ACQUISITION OF COMPLEX THERAPEUTIC PROCEDURES IN PRE-REGISTRATION PHYSIOTHERAPY EDUCATION USING MOTOR LEARNING PRINCIPLES

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Dissemination of work

Three studies from previous modules of the professional doctorate have been published. The full papers (marked *Sattelmayer) are appended on page 219 and following)

*SATTELMAYER, M., ELSIG, S., HILFIKER, R. and BAER, G., 2016. A systematic review and meta-analysis of selected motor learning principles in physiotherapy and medical education. *BMC Medical Education.* 16**,** p. 15.

*SATTELMAYER, M., HILFIKER, R. and BAER, G., 2017. A systematic review of assessments for procedural skills in physiotherapy education. *INTERNATIONAL JOURNAL OF HEALTH PROFESSIONS.* 4**,** pp. 53-65.

SATTELMAYER, M., HILFIKER, R. and BAER, G., 2016. Développement d'une échelle d'évaluation des compétences procédurales dans la formation en physiothérapie: une étude de validation de la théorie de la réponse par item. *Kinésithérapie, la Revue.* 16**,** p. 38.

Abstract

This thesis focuses on the acquisition of complex procedures in physiotherapy education using two motor learning principles and reports on five separate key studies:

> Chapter II: A study about the definition of procedural skills in physiotherapy education using a systematic review design and a text mining approach.
> Chapter III: A systematic review about the effectiveness of different attentional foci on the acquisition of complex motor skills.
> Chapter IV: A critical analysis of mental practice interventions in health professions education: A condensed review.
> Chapter V: The development and validation of a mental practice script for a transfer procedure for people with hemiparesis after stroke.
> Chapter VI: A randomised controlled trial evaluating the effectiveness and feasibility of two motor learning principles on the acquisition of complex procedures in physiotherapy education

Chapter II: Randomised controlled trials and systematic review reporting about procedural skills were systematically searched. A qualitative analysis identified several relevant sub-concepts of procedural skills such as "execution of a motor task" or "decision-making". A quantitative analysis was performed to identify term occurrences and to create a network of associations between the used terms. Based on both analyses a novel definition of "procedural skills in physiotherapy education" was proposed and operationalised.
Chapter III: Studies comparing the effectiveness of an external focus of attention versus an internal focus of attention on the acquisition of complex motor skills were systematically searched in Medline, Embase, ERIC and SPORTDiscus. Findings of a meta-analysis were in favour of external focus of attention (SMD: -0.54; 95% CI between -0.86 and -0.22). Meta-regression identified "task complexity" as potential relevant predictor variable.
Chapter IV: This study analysed how mental practice interventions designed for health professions were defined, structured and adhered to proposed best practice variables of mental practice.
Chapter V: A mental practice script for a transfer procedure for people with hemiparesis was developed and validated in this study. Experienced physiotherapists were interviewed how they perform the procedure. Analysis of the interviews resulted in the development of a preliminary script, which was piloted to validate the manuscript.
Chapter VI: The effectiveness and feasibility of two motor learning principles (mental practice and focus of attention) was evaluated on two different task procedures in pre-registration physiotherapy education. The difference between mental practice and no mental practice was not statistically significant. Findings of the comparison of the attentional focus differed between task procedures. An internal focus of attention was more effective for the acquisition of a transfer task procedure. For the second task procedure in vestibular rehabilitation the performance between the internal and external focus of attention groups was similar.

Conclusions:
This was the first study, to the authors knowledge, that investigated the acquisition of complex motor task skills in pre-registration physiotherapy students. The results presented in this thesis will help inform educators and researchers regarding the use of mental practice and different attentional foci to support the teaching approach for acquisition of complex skills in physiotherapy education.

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List of abbreviations

APSPT 29	assessment of procedural skills in physiotherapy education 29
CC	complete cases analysis
CRT	Canalith repositioning technique
EFA	external focus of attention
FoA	focus of attention
HPE	health professions education
IFA	internal focus of attention
LEArN	Learning of procEdures in physiotherApy education
LOCF	last observation carried forward analysis
MI	multiple imputations
MIQ	mental imagery questionnaire
MP	mental practice
mdn	median
nMP	no mental practice
PSC	procedure specific checklist
SD	standard deviation
SMD	standardised mean difference

1 General introduction

Procedural skills are a central element in the education of future physiotherapists (World Confederation for Physical Therapy 2017) and of other health professions (Norris et al. 1997). Procedural skills relate to the execution of a practical task such as performing a soft tissue mobilisation or teaching a person with a stroke to perform a safe transfer to ground. A procedure can be related to a diagnostic intervention or to a therapeutic intervention. Incorrectly performed procedures may result in ineffective treatments or serious problems and adverse events to patients and health professionals. For example, in a recent systematic review, Gorrell et al. (2016) reported mild adverse events following spinal manipulation in n = 61 studies and major adverse events were reported in n = 2 studies (from a total of 368 included studies). Anecdotally it is known that sometimes physiotherapist perform practical procedures in clinical situations with poor working positions, which might cause incorrect application of the procedure or musculoskeletal injuries (Jackson and Liles 1994). Glista and co-workers (2014) reported a considerable worsening of posture was observed in physiotherapy students during their study examining posture at the beginning and the end of a physiotherapy degree programme.

The importance of correctly acquiring procedural skills in health professions education (HPE) can be seen by the increasing volume of published studies on the topic. New procedures in healthcare are developed constantly, which requires that educational programmes either increase the amount of taught procedures in their curricula or select new procedures and discard existing procedures. This dilemma highlights the need for effective and feasible methods to support learners and educators. Several methods have been introduced to respond to this challenge. For example, internet-based learning applications or virtual reality simulation are increasingly used in HPE. However, the use of those technology-based methods require considerable resources. Within the discipline of movement sciences effective training principles exist, which require substantial less resources. Sometimes they

only require a change of wording when the learners receive instructions or feedback. Recently, some researchers (e.g. Wulf et al. 2010) have suggested applying a specific set of training principles, so called "motor learning principles", derived from the learning of movement skills to the learning of procedural skills in HPE.
However, no-one has looked at this in the acquisition of complex skills by novice physiotherapists. Therefore, research is required to analyse whether motor learning principles can be used to increase skill acquisition.
For the purpose of the work reported in this thesis the following definition of motor learning is used: "A change in the capability of a person to perform a skill that must be inferred from a relatively permanent improvement in performance as a result of practice". In motor learning theory various motor learning principles are proposed (Schmidt and Lee 2011). These principles are derived from motor learning research, which can be used to structure or influence motor skill acquisition (e.g. such as the way feedback is provided). For this thesis, early work undertaken by the author, identified two motor learning principles (mental practice and focus of attention) which were selected as relevant for application in physiotherapy education.
This thesis reports packages of work undertaken as part of a Professional Doctorate programme of study with a focus on exploring the application of selected motor learning principles on the acquisition of complex therapeutic procedures in physiotherapy education. Below a general overview of the thesis is presented.

In **Chapter 1** a general overview of this thesis is presented.
Chapter 2 presents work that explored the existing definitions of procedural skills in HPE. Published randomised controlled trials and systematic reviews relating to procedural skills were systematically searched and identified studies which were quantitatively explored with the help of text mining. The identified definitions of procedural skills were qualitatively analysed for relevant sub-concepts of procedural skills such as execution of a motor task, safety or decision-making. Based on the analyses a novel definition of procedural skills in HPE was proposed, with an accompanying comprehensive operationalisation of the definition. The specific aims

of this work package were: i) to systematically search existing definitions of procedural skills and to analyse the scope and content of definitions and ii) to redefine the concept “procedural skills” in relation to physiotherapy education. The findings of this study (i.e. the definition and operationalisation) were used in the following work packages as conceptual background information.

The next two chapters, chapter 3 and chapter 4, present in-depth exploration of the evidence to support the two motor learning principles to be explored in this thesis - namely Focus of Attention (FoA) and Mental Practice (MP).

Chapter 3 reports the findings of a systematic review and a meta-regression to investigate the influence of variables including “skill complexity” and “previous experience”. The specific aim was to evaluate the application of an external focus of attention (EFA) compared to an internal focus of attention (IFA) on performance and skill acquisition of complex motor skills.

Skill complexity was identified as a potentially relevant predictor variable and the evidence for the influence of different foci of attention on skill acquisition are considered. Within **Chapter 4** it was analysed how MP is defined in studies using this motor learning principle for procedures in HPE. In addition, it was appraised how MP interventions were designed regarding key variables such as timing, instructions and duration. The findings of this chapter are linked to chapter 5. They were used to establish a valid method to design a mental practice script.

In **Chapter 5** the development and validation of a MP script for a transfer procedure for people with hemiparesis after stroke is reported. An approach presented by Arora et al. (2010) was followed to design a script following interviews with experienced physiotherapists. Analysis of the interviews resulted in the development of a preliminary script, which was piloted to validate the manuscript. This pilot work showed promising findings in relation to ability to perform the procedure mentally. The final script was used to inform the final package of work.

In **Chapter 6** a randomised controlled trial is presented (the LEArN trial), which explored the feasibility and effectiveness of using two motor learning principles (i.e. MP and FoA) in physiotherapy education. Two procedures were selected to evaluate both motor learning principles. The first procedure was a transfer to the ground and the second procedure was a set of vestibular rehabilitation techniques. Participants were randomised to the following groups: MP against no mental practice (nMP) and EFA against an IFA. The performance of the participants was measured post-acquisition and after a retention interval of two weeks. The primary objective was to estimate the effectiveness of the motor learning principles on performance of procedural skills. The secondary objective was to analyse the feasibility of this study. **Chapter 7** is used to present the conclusion of this thesis and propose recommendations for educational practice and future research.

A flow chart illustrating the work packages and preparatory work not included in the thesis is presented in Figure 1.1.

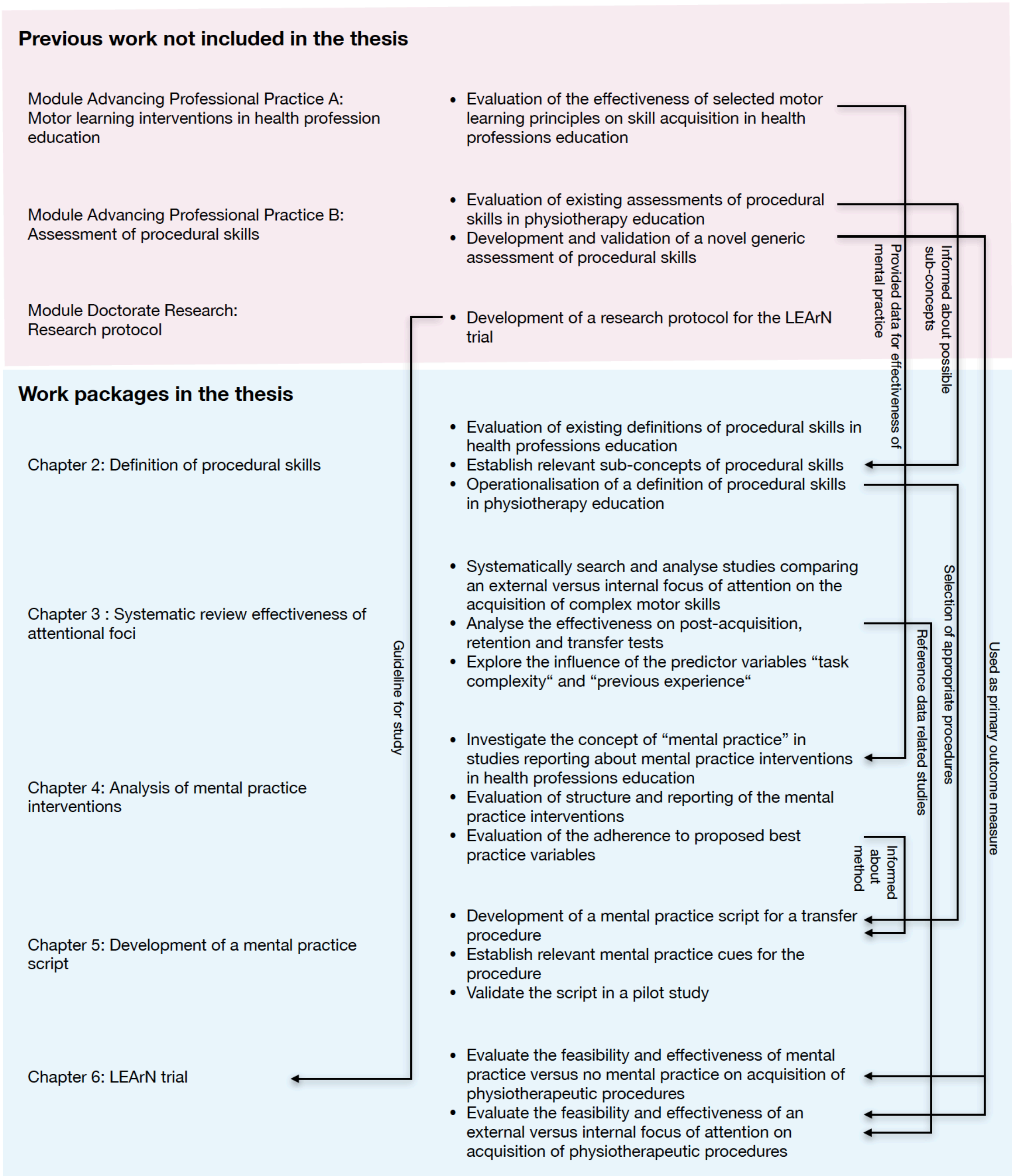
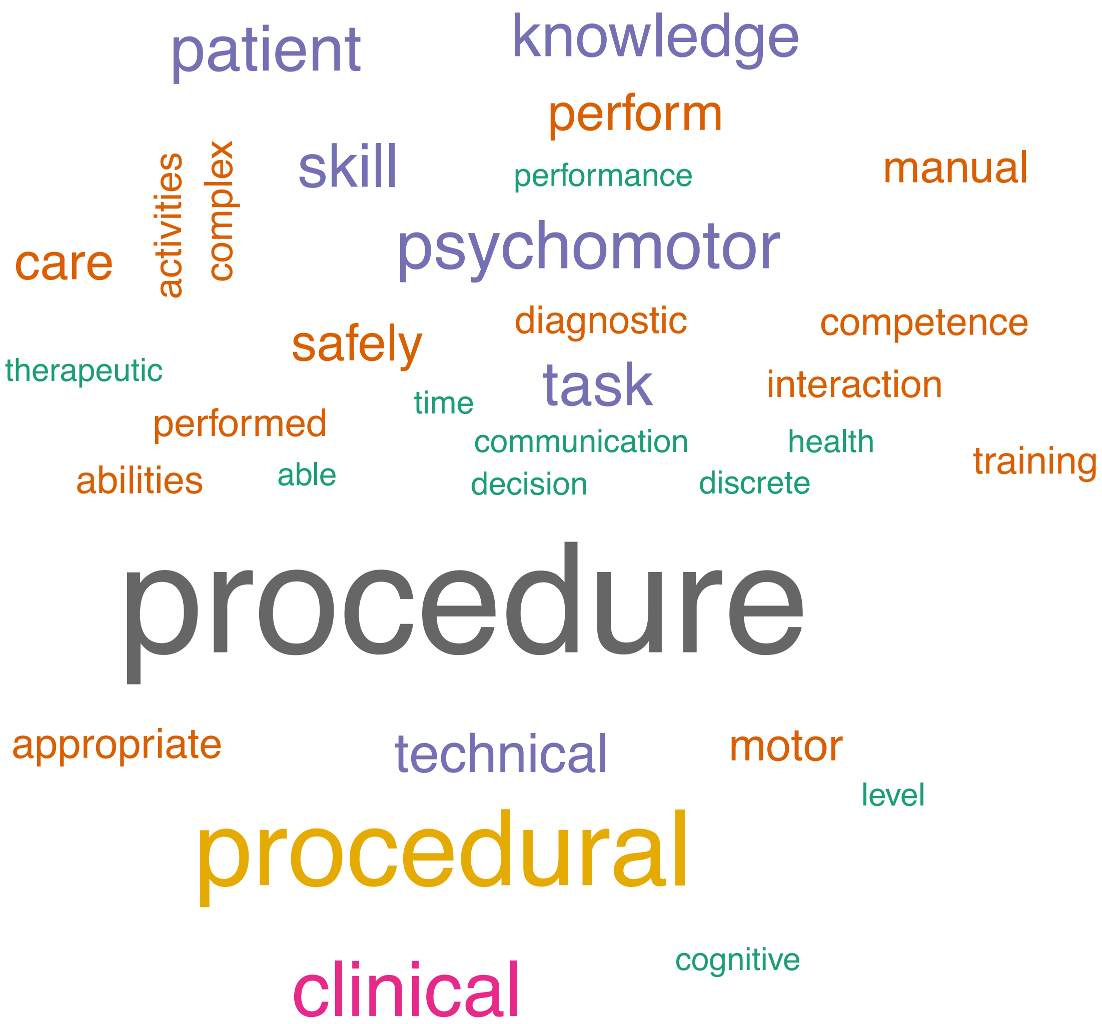


Figure 1.1 Overview of work packages in the thesis with information about chapters, aims, previous work and links between work packages

2 On the definition of procedural skills in physiotherapy education: A content analysis using text mining



2.1 Introduction - procedural skills definition

Procedural skills are a central element in physiotherapy education (World Confederation for Physical Therapy 2017) but no clear definition based on consensus has been proposed for this concept. A frequently used definition states that procedural skills are "a motor skill involving a series of discrete responses each of which must be performed at the appropriate time in the appropriate sequence" (Kent 2007, p. 437).

Michels and colleagues (2012) reported that procedural skills are frequently classified under the category "clinical skill". This increases the complexity to define procedural skills. Because authors use the term "clinical skills" differently and different tasks and skills are integrated in the concept "clinical skills". For example, the General Medical Council uses clinical skills and procedural skill in the same category (General Medical Council 2004). In contrast, within the Scottish doctor learning outcomes clinical skills are separated from procedural skills (Simpson et al. 2002).

Some authors refer to "procedural skills" as being part of the category "psychomotor skills", defined as: "… motor skill, some manipulation of material, or some act which requires a neuromuscular action" (Simpson 1966, p. 17). For example, Jelovsek et al. (2013) used both terms synonymously in their systematic review about assessment tools for procedures in medical education. Despite the difficulties to build an accepted definition of the concept "procedural skills" it is accepted that these skills are an important element in university curricula (World Confederation for Physical Therapy 2017).

Within this chapter a definition of "procedural skills" is proposed. In later chapters the evaluation of procedural skills will be explored and interventions for procedural skills will be investigated. For both purposes a clear definition of the concept is required, otherwise it is difficult to focus on procedural skills (e.g. it is unclear which items should be evaluated to gain understanding of the whole spectrum) or it may be questionable how interventions should be designed to allow the acquisition of complex procedural skills. Nickel et al. (2017) recently undertook a systematic review and reported why words are important in a health-related context. They observed that changing the terminology used had considerable influence on management preferences and psychological outcomes in various patient subgroups. Therefore, the aim of this section of work was to define the concept "procedural skills" in physiotherapy education. To achieve this aim two objectives were specified:

- To systematically search existing definitions of procedural skills in published literature and to analyse the scope and content of definitions
- To redefine the concept "procedural skills" in relation to physiotherapy education.

2.2 Methods - Procedural skills definition

The design of this study was a systematic review with an analysis based on text mining methods and manual coding.

2.2.1 Inclusion and exclusion criteria

These criteria were set to include studies:

- Studies had to report a definition or a description of "procedural skills".
- The study setting had to be based in medical or HPE.
- Studies reporting definitions in other fields were included when the definition of procedural skill could be used in the context of HPE.
- Studies should be published as open access articles. This criterion was regarding the principle of the open science movement that all research should be publicly available.
- No restrictions were set regarding publication language and date of publication.

The following criteria were used to exclude studies:

- No reported definition of procedural skills in general. Studies defining specific procedural skills were excluded. Definitions of specific procedures are considerably different from generic definitions. For example, Voelker et al.

(2016) used among others these words to define a procedure from cardiology "Careful co-axial catheter-engagement of the left ostium under fluoroscopic guidance" (p. 77). These terms are useful to precisely define all parts of the specific procedure but they do not apply to procedures outside this discipline.

- The definition should provide a minimal set of information. Statements such as procedural skills are important, vital or crucial were not included in the review.
- No minimum definition of what a procedural skill is.

2.2.2 Search methods for identification of studies

To identify definitions of the concept "procedural skills" it was expected hat randomised controlled trials evaluating various interventions to improve the ability to perform a procedural skill should report their definition of procedural skills. This was based upon the assumption that "procedural skill" would be a key concept in these articles. For example, the consort statement encourages authors to report the "scientific background and explanation of rationale" in the introduction section (Schulz et al. 2010). To identify these articles Medline via Pubmed was searched with the following search strategy:

- The search term "procedural skill*" was combined with the Cochrane filter for randomized controlled trials (Lefebvre et al. 2011)

A second source of potential eligible studies were systematic reviews. As above, it was assumed that review authors should report the context of their review. For example, the PRISMA statement asks authors to "describe the rationale for the review in the context of what is already known" (Moher et al. 2009). It was assumed that a definition of the key concept of the reviews reporting about procedural skills would be part of this rationale. To identify systematic reviews Medline via Pubmed was searched with the following search strategy:

- The search term “procedural skill*” was combined with the Pubmed filter for systematic reviews (Shojania and Bero 2001)

Systematic reviews were not limited to interventional reviews. Systematic reviews reporting about other aspects of procedural skills were also included. Furthermore, reference checking and grey literature complimented the above-mentioned search strategies. The complete search string is presented in Appendix i.

2.2.3 Study selection

All potential eligible records were included in an electronic reference management system (Endnote X7). Duplicates were removed and a single author (MS) screened all records regarding the selection criteria. Afterwards, full-text articles were searched for definitions of procedural skills. Only articles with a definition of procedural skills remained in the review (Figure 2.1 on page 13).

2.2.4 Data extraction

The following information was extracted from all included studies:

- General information: authors, year of publication, discipline (i.e. field of study such as “medical education”)
- The definitions of procedural skills were extracted
- Bibliometric information: The amount of citations was searched for each included study. Google scholar citations were chosen because of adequate functionality (Harzing and Alakangas 2016) and a superiority to identify citations compared to other services such as Scopus or ResearchGate (Thelwall and Kousha 2017).

2.2.5 Analysis using manual coding

All included definitions were analysed using manual coding (qualitative analysis), based on previous work, regarding possible sub-concepts of procedural skills. Each definition was analysed as to whether a connection existed between “procedural skills” and “preparation”, “knowledge”, “decision-making”, “safety”, “communication”, “execution of motor tasks”, “comfort” and other not a priori specified sub-concepts.

A previous systematic review, by the author, had identified concepts and sub-concepts from existing assessments for procedural skills (Sattelmayer et al. 2017). Furthermore, a generic assessment for procedural skills in physiotherapy education (using the above mentioned sub-concepts) has been validated and uni-dimensionality confirmed (Sattelmayer et al. 2016b). Therefore, these sub-concepts were regarded as relevant coding categories. To avoid missing potentially relevant concepts, an open category “other sub-concepts” was added to the coding categories.

As presented earlier Michels et al. (2012) discussed that a considerable overlap exists between “procedural skill” with the concepts “clinical skill” and “psychomotor skill”. To be able to further analyse the interrelatedness between the three concepts it was coded whether the concepts “clinical and psychomotor skills” were used within the definition of “procedural skills”.

2.2.6 Analysis using text mining

Text mining (quantitative analysis) of definitions was performed in the statistical package R (version 3.4.0) with the help of the text mining package “tm” (Feinerer 2017). The following steps were performed:

- A corpus containing all definitions was built.
- Data were prepared for analysis (i.e. punctuation was removed, transformation to lower case letters, digits were removed, stop words were removed and white space was stripped).
- Data were checked manually and some terms were transformed (e.g. the terms “procedure” and “procedures” were combined. The same approach was applied to “skill” and “skills”).
- A document term matrix was constructed. This matrix consisted of the included studies (rows) and the used terms (columns). Table 2.1 is an illustration of this matrix.

- Based on the document term matrix frequencies of terms were analysed. Frequently occurring terms were selected for further analysis (a minimum frequency of five occurrences was defined as sufficient frequency in the set of definitions).
- Correlations between frequent terms were analysed and a network was created to visualise the associations between terms. For the analysis of correlations, the "corrrplot" package (Wei and Simko 2016) was used. Correlations were calculated based on the term occurrences in the document term matrix (e.g. if term "x" appeared frequently with term "y" a high correlation between the two terms was analysed). Correlations were interpreted as follows: > 0.5 as moderate and > 0.7 as high (Mukaka 2012)
- To provide a visual representation of the concept "procedural skill" a word cloud was prepared.
- A hierarchical cluster analysis was performed to identify cluster of definitions. Euclidian distances between terms were analysed using the method Ward2 (Murtagh and Legendre 2014). .

Table 2.1 Example of a document term matrix

	skill	procedure	clinical	motor	…
Study 1	0	2	0	1	…
Study 2	1	1	1	0	…
Study 3	2	1	0	0	…

NB. The matrix can be interpreted as: Study 1 used the term "procedure" twice and the term "motor" once in their definition of procedural skills. They did not use the terms "skill" and "clinical".

The findings of both analyses (i.e. manual coding and text mining) were synthesised to propose a definition and operationalisation of procedural skills, which could be used as conceptual background information of this thesis. The operationalisation was based on three parts. First, the findings of the text mining analysis were used to identify frequent terms and correlations of frequent terms in definitions of procedural skills. The correlations were visualised in a term association network and based on the visualisation a definition was proposed. Relevant information of the network was incorporated into a definition and its operationalisation.

Second, the findings of the manual coding were used to identify relevant sub-concepts of "procedural skills" and third similarities and dissimilarities between the terms "psychomotor skills", "clinical skills" and "procedural skills" were integrated into the definition.

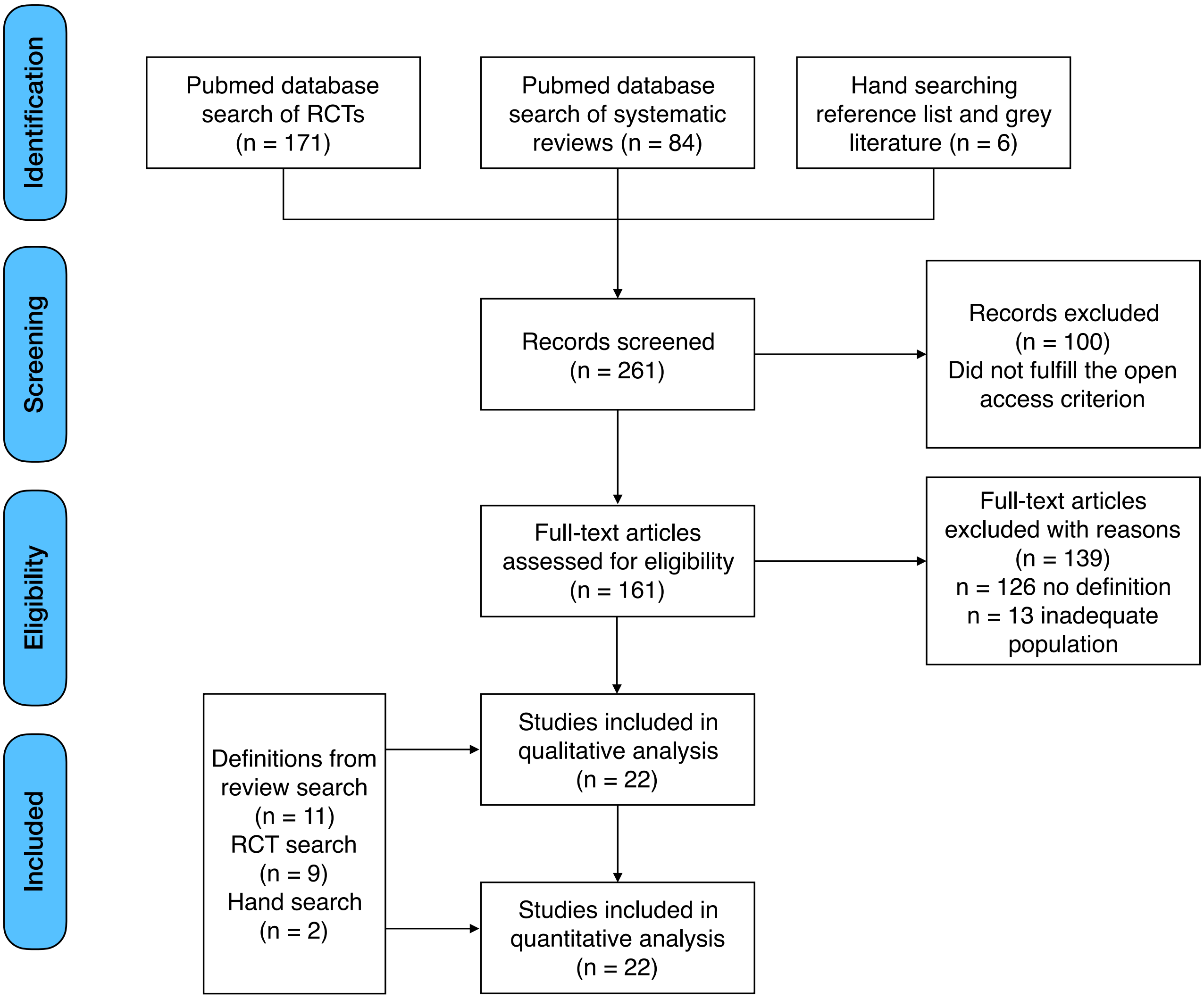


Figure 2.1 Flow chart of search and selection process

2.3 Results - procedural skills definition

The results of this work are reported in three sections. First, results of the search and selection process are presented. Second, findings of the analysis using manual coding are provided. The last section reports the quantitative analysis using text mining.

2.3.1 Findings of the search

The search identified 261 potential eligible studies (Figure 2.1). The first search on Pubmed yielded n = 171 potential relevant RCT's. The second search on Pubmed recognised n = 84 Reviews. Six articles were found by reference checking and screening of grey literature. The search for full-texts identified that 100 articles were not publicly available and were therefore excluded (i.e. they did not full fill the open access criterion). Analysis of n = 161 full-texts articles revealed that n = 139 did not report a definition of procedural skills fitting the in- and exclusion criteria and therefore were excluded. Two categories of missing specific definitions were noted: i) Studies did not define procedural skills in a general sense, instead definitions of specific procedural skills were presented. For example, Straus et al. (2006) defined lumbar puncture or Voelker et al. (2016) defined procedures in interventional coronary medicine and ii) the articles referred to procedural skills as common knowledge and stated that acquisition of those is essential (Lund et al. 2012) a core learning outcome (Burch et al. 2005) or technically challenging (Haycock et al. 2009). Within those procedural skills were the execution of a procedure in a specific health profession but no further specification was available.

Thirteen studies were excluded because the field of study was not healthcare related (e.g. children with difficulties in mathematics (Chan and Ho 2010)). A final 22 studies were included in the analysis providing definitions of procedural skills (Norris et al. 1997; Simpson et al. 2002; General Medical Council 2004; Kent 2007; Chenkin et al. 2008; McKinley et al. 2008a; McKinley et al. 2008b; Jackson et al. 2009; Ahmed et al. 2011; Touchie et al. 2013; Vapenstad and Buzink 2013; Nicholls et al. 2014; Grover et al. 2015; Maytin et al. 2015; Ojha et al. 2015; Hernandez-Padilla et al. 2016; Sattelmayer et al. 2016a; The Royal Australian College of General Practitioners 2016;

Walsh 2016; Brunette and Thibodeau-Jarry 2017; Cheung et al. 2017; Sattelmayer et al. 2017). All included definitions of procedural skills are presented in Table 2.2. From the 171 hits of the first search identifying RCT's only 9 studies provided definitions, which were eligible for inclusion in this report (i.e. 5.3%). In contrast, the 84 hits from the search for systematic reviews resulted in inclusion of 11 definitions (i.e. 13.1%).

All included studies were qualitatively (with manual coding) and quantitatively (with text mining) analysed. An overview of the search and selection process is presented in Figure 2.1. Studies were included from a relatively broad field covering disciplines such as physiotherapy, medical education, health care workers, cardiac care and others. Two studies (Simpson et al. 2002; Kent 2007) were appraised as providing influential definitions indicated by more than 200 citations on Google Scholar (June 2017).

Table 2.2 Included definitions of procedural skills

Study	Definition
(Ahmed et al. 2011)	“Clinical competence is a combination of cognitive factors (acquiring and applying knowledge, decision making, using resources, and learning from expertise), personality traits (communication skills), and psychomotor skills (technical skills/ procedural skills). Assessment of technical skills is a crucial component for an increasing range of specialties” (Ahmed et al. 2011, p. 470).
(Brunette and Thibodeau-Jarry 2017)	“The mastering of many procedural skills is mandatory to safely work in care units” (Brunette and Thibodeau-Jarry 2017, p. 122)
(Chenkin et al. 2008).	“Procedural skill training involves a complex integration of procedural knowledge and psychomotor skill, which often includes live demonstrations by a clinical expert” (Chenkin et al. 2008, p. 950).
(Cheung et al. 2017).	“In procedural skills, and likely for clinical skills more generally, we propose integrating procedural and conceptual knowledge, which parallel clinical knowledge and basic science respectively” (Cheung et al. 2017, p. 3).
(General Medical Council 2004).	“The most important clinical skill is to be aware of the limits of their own knowledge and abilities. To be able to do the following safely and effectively in the workplace”. “Show that they can, at the right time, recognise common emergencies, identify a working diagnosis and manage care, to a level of competence appropriate to their position in the team and provide follow-up care for these patients in a range of clinical settings. Show good practice in prescribing” (General Medical Council 2004, p. 16).
(Grover et al. 2015).	“Tools that define procedural competence indicate that proficiency is required in domains: technical or psychomotor, cognitive, and integrative competencies wherein trainees can use learned skills to perform procedures in varying contexts” (Grover et al. 2015, p. 1073).
(Hernandez-Padilla et al. 2016)	“Being competent in clinical or procedural skills, requires individuals not only to gain knowledge and psychomotor skills in the procedure but also to achieve a certain level of self-confidence in their capabilities to carry it out” (Hernandez-Padilla et al. 2016, p. 46).
(Jackson et al. 2009)	“Procedural skills (are related to) performance of tests or procedures. Regard for patient comfort and dignity during procedure” (Jackson et al. 2009, p. 930).
(Kent 2007)	“Procedural skills are: a motor skill involving a series of discrete responses each of which must be performed at the appropriate time in the appropriate sequence” (Kent 2007, p. 437).
(Maytin et al. 2015)	“Ability to describe planned procedure, procedure objective, procedure preparation, the method of intraoperative monitoring, and the sedation plan. Additionally, psychomotor cognitive skills were assessed” (Maytin et al. 2015, p. 320).

Study	Definition
(McKinley et al. 2008a)	"These (procedural) skills require manual dexterity and health-related knowledge which are aimed at the care of a single patient" (McKinley et al. 2008a, p. 620).
(McKinley et al. 2008b)	"Any discrete task requiring manual skills and health related knowledge which is directly related to the care of single patient. A clinical procedure is therefore a social interaction and a competent practitioner will perform the procedure correctly in a patient-centred way in the broader context of healthcare and the healthcare team" (McKinley et al. 2008b, p. 340).
(Nicholls et al. 2014)	"The literature demonstrates that procedural, technical, or task-based skills are used interchangeably with psychomotor skills. In each health discipline, a psychomotor skill is defined by the unique skills that profession uses". … "In surgical medicine, Kovacs defined a psychomotor skill as the mental and motor activities required to execute a manual task whereas Rose and Best coming from a physiotherapy background, further refined the definition to include being performed correctly, efficiently and safely. In the nursing literature, Bjork stated that a technical skill is a refined pattern of movement or performance based upon and integrated with the perceived demands of the situation. Procedural skills are the unique mental and motor activities required to execute a manual task safely and efficiently for each clinical situation" (Nicholls et al. 2014, p. 1350).
(Norris et al. 1997)	"Procedures are an integral part of medical practice". … "Many physicians enjoy using their hands to perform diagnostic and therapeutic procedures" (Norris et al. 1997, p. S64). … "The patient safety is a major consideration in procedural training of physicians" (Norris et al. 1997, p. S67). … "Students must be trained to perform procedures safely and well". (Norris et al. 1997, p. S69)
(Ojha et al. 2015)	"Attaining complex procedural skills requires the balanced involvement of several facets including psychomotor, clinical judgment, communication, decision-making, and patient-focused interaction abilities and cannot be brought to fruition through clinical exposure alone". (Ojha et al. 2015, p. 3)
(The Royal Australian College of General Practitioners 2016)	"Procedural skills encompass the areas of clinical care that require physical and practical skills of the clinician in order to accomplish a specific and well characterised technical task, or procedure. A procedure is a manual intervention that aims to produce a specific outcome during the course of patient care; it may be investigational, diagnostic, and/or therapeutic, and is usually able to be performed in the ambulatory primary healthcare setting. Inherent in the term of medical procedure is the concept of invasiveness. This may involve discomfort for the patient and a risk of adverse effects and complications associated with the procedure in addition to those associated with the medical condition which initially necessitated the procedure. Procedural competency often involves the acquisition of specific psychomotor skills". (The Royal Australian College of General Practitioners 2016)
(Sattelmayer et al. 2016a)	"Procedural skills are motor skills involving a series of discrete responses each of which must be performed at the appropriate time in the appropriate sequence. A procedure can serve different purposes (e.g. it may be a diagnostic or therapeutic procedure. Procedures

Study	Definition
	can be simple tasks with only a few parts or they can involve complex sequences of multiple activities that are linked together. Each procedure requires acquisition of unique motor skills. Because of this similarity we are using the terms procedural skills and motor skills interchangeably". (Sattelmayer et al. 2016a, p. 2).
(Sattelmayer et al. 2017)	"Procedural skills were characterised with the following features: a) they involve the execution of a procedural task (e.g., a manual or a practical task), b) involvement of technical equipment may be possible but this is not a prerequisite of procedural skills, c) the character of a procedure can be diagnostic, evaluative or interventional and d) procedures can range from simple tasks with few parts to complex sequences involving multiple activities". (Sattelmayer et al. 2017, p. 54)
(Simpson et al. 2002)	"Procedures that the new graduate should be able to carry out unsupervised" … (specific procedures not listed here). "Some of these procedures also feature in the domain of "Patient Investigation" and many others are not specifically mentioned here as they should be covered by normal physical examination. Procedures from the domain "Measuring and recording" and "Administering and doing" are … (specific procedures not listed here)". (Simpson et al. 2002, p. 138)
(Touchie et al. 2013)	"Acquiring these skills requires the development of several different abilities including psychomotor, clinical judgment, communication, decision making, and patient-focused interaction abilities". (Touchie et al. 2013, p. 1)
(Vapenstad and Buzink 2013)	"To safely perform a procedure, the surgeon needs technical, theoretical, and interpersonal skills" (Vapenstad and Buzink 2013, p. 364). A procedural task is defined as a simulator exercise that offers training in the performance of a complete or part of a surgical procedure, simulating the anatomical landscape in which the specific procedure takes place, pathophysiological behaviour, and interaction characteristics of the instruments used to perform the procedure in real life". (Vapenstad and Buzink 2013, p. 365)
(Walsh 2016)	"Procedural competence has been defined as the minimum level of skill, knowledge, and or expertise, derived through training and experience, required to safely and proficiently perform a task or procedure". (Walsh 2016, p. 358)

2.3.2 Analysis using manual coding

The qualitative synthesis relates to the analysis of integrated sub-concepts of procedural skills and the similarity between the concepts "procedural skills", "psychomotor skills" and "clinical skills".

Table 2.3 Identified sub-concepts in definitions about procedural skills

Study	Discipline	Google.Scholar.citations	Preparation	Knowledge	Decision.making	Safety	Communication	Motor.task	Comfort	Other.concepts	Summary.concepts
Ahmed 2011	Medical education	115	✖ Not specified	✖ Not specified	✖ Not specified	✖ Not specified	✖ Not specified	✔ YES	✖ Not specified	Technical skills	2
Bruntte 2017	Cardiac care	0	✖ Not specified	✖ Not specified	✖ Not specified	✔ YES	✖ Not specified	✖ Not specified	✖ Not specified	Not specified	1
Chenkin 2008	Emergency medicine	69	✖ Not specified	✔ YES	✖ Not specified	✖ Not specified	✖ Not specified	✔ YES	✖ Not specified	Learned by demonstrations	3
Cheung 2017	Medical education	0	✖ Not specified	✔ YES	✖ Not specified	✖ Not specified	✖ Not specified	✖ Not specified	✖ Not specified	Not specified	1
GMC 2004	Medical doctors	0	✖ Not specified	✔ YES	✔ YES	✔ YES	✔ YES	✔ YES	✖ Not specified	Awareness of own limits	6
Grover 2015	Gastroenterology	11	✖ Not specified	✔ YES	✔ YES	✖ Not specified	✖ Not specified	✔ YES	✖ Not specified	Integrative competencies	4
Hernandez-Padilla 2016	Nursing	3	✖ Not specified	✔ YES	✖ Not specified	✖ Not specified	✖ Not specified	✖ Not specified	✖ Not specified	Self-confidence	2
Jackson 2009	Medical education	31	✖ Not specified	✖ Not specified	✖ Not specified	✖ Not specified	✖ Not specified	✔ YES	✔ YES	Patient's dignity	3
Kent 2007	Sport Science & Medicine	236	✖ Not specified	✖ Not specified	✖ Not specified	✖ Not specified	✖ Not specified	✔ YES	✖ Not specified	Timing and sequence	3
Maytin 2015	Medical education	2	✔ YES	✖ Not specified	✖ Not specified	✔ YES	✖ Not specified	✔ YES	✖ Not specified	Able to describe objective	4
McKinley 2008a	Health service staff	17	✖ Not specified	✔ YES	✖ Not specified	✖ Not specified	✖ Not specified	✔ YES	✖ Not specified	Not specified	2
McKinley 2008b	Health care workers	56	✖ Not specified	✔ YES	✖ Not specified	✖ Not specified	✔ YES	✔ YES	✖ Not specified	Manual skills, team and humanistic aspects, patient centred	6
Nicholls 2014	Health professions	20	✖ Not specified	✔ YES	✖ Not specified	✔ YES	✖ Not specified	✔ YES	✖ Not specified	Situational demands, technical skills	5
Norris 1997	Primary care physicians	49	✖ Not specified	✖ Not specified	✖ Not specified	✔ YES	✖ Not specified	✔ YES	✖ Not specified	Use of hands	3
Ohja 2015	Pediatrics	6	✖ Not specified	✖ Not specified	✔ YES	✖ Not specified	✔ YES	✔ YES	✖ Not specified	Patient-focused interaction abilities	4
RACGP 2016	General practitioners	0	✖ Not specified	✖ Not specified	✖ Not specified	✔ YES	✖ Not specified	✔ YES	✔ YES	Invasiveness	4
Sattelmayer 2016	Medical education	3	✖ Not specified	✖ Not specified	✖ Not specified	✖ Not specified	✖ Not specified	✔ YES	✖ Not specified	Complexity	2
Sattelmayer 2017	Physiotherapy	0	✖ Not specified	✖ Not specified	✖ Not specified	✖ Not specified	✖ Not specified	✔ YES	✖ Not specified	Manual or practical skill, technical skill, complexity	4
Simpson 2002	Medical education	224	✖ Not specified	✖ Not specified	✔ YES	✖ Not specified	✖ Not specified	✔ YES	✖ Not specified	Measuring and recording	3
Touchie 2013	Internal medicine	11	✖ Not specified	✖ Not specified	✔ YES	✖ Not specified	✔ YES	✔ YES	✖ Not specified	Patient-focused interaction abilities	4
Vapenstad 2013	Surgery	35	✖ Not specified	✔ YES	✖ Not specified	✖ Not specified	✔ YES	✔ YES	✖ Not specified	Technical skills, interaction characteristics of instruments	5
Walsh 2016	Gastroenterology	1	✖ Not specified	✔ YES	✖ Not specified	✔ YES	✖ Not specified	✖ Not specified	✖ Not specified	Expertise	3

2.3.2.1 *Identified sub-concepts of procedural skills*

Analysis of the 22 included definitions identified that “execution of a motor task” was a key sub-concept used by most of the definitions (n = 18). “knowledge” was a relevant sub-concept in n = 9 definitions. Less frequently repeated sub-concepts included “safety” (n = 7), “communication” (n = 5) and “decision-making” (n= 5). The sub-concepts “comfort” and “preparation” were only rarely identified in the included definitions (n = 2 and 1). Several sub-concepts not previously defined were discovered (reported only when used by more than a single group of authors): “technical skills” (n = 4), “patient-focussed interaction abilities” (n = 3) and “manual skills” (n = 2). An overview of all identified sub-concepts related to the definition of procedural skills is presented in Table 2.3. Furthermore, the included definitions were analysed regarding the number of integrated sub-concepts. Identified sub-concepts ranged between 1 and 6 per definition (m: 3.4; SD: 1.4). Two sources were appraised as providing relatively broad definitions of procedural skills. The General Medical Council (2004) and McKinley et al. (2008b) integrated six sub-concepts in their definitions. In contrast Cheung et al. (2017) and Brunette and Thibodeau-Jarry (2017) included only one sub-concept in their definition.

2.3.2.2 *Similarity between clinical skills, psychomotor skills and procedural skills*

Six definitions (Chenkin et al. 2008; Ahmed et al. 2011; Touchie et al. 2013; Nicholls et al. 2014; Ojha et al. 2015; The Royal Australian College of General Practitioners 2016) were classified as relating the concepts “procedural skills” and “psychomotor skills” to each other. One definition used the concepts “procedural skills” and “psychomotor skills” interchangeably (Nicholls et al. 2014). The remaining five definitions used “psychomotor skills” as a concept, which is involved in the acquisition of motor skills, but did not use the two concepts interchangeably. For example, Touchie et al. (2013) reported that:

> “Acquiring these skills requires the development of several different abilities including psychomotor abilities” (Touchie et al. 2013, p. 1).

The definitions from four groups (General Medical Council 2004; Ahmed et al. 2011; Hernandez-Padilla et al. 2016; Cheung et al. 2017) analysed the interrelatedness between the concepts "clinical skills" and "procedural skills" (i.e. these authors specifically used the concept "clinical skill" in their definitions). In the definition of Hernandez-Padilla et al. (2016) there is no clear distinction between the two concepts and both concepts are used as synonyms.

> "Being competent in clinical or procedural skills, requires individuals not only to gain knowledge and psychomotor skills in the procedure but also … " (Hernandez-Padilla et al. 2016, p. 46).

Whereas the other three authors regard clinical skills as more general concept and procedural skills are categorised within this concept. For example:

> "In procedural skills, and likely for clinical skills more generally, we propose integrating procedural … ." (Cheung et al. 2017, p. 4).

2.3.3 Analysis using text mining

This section reports term occurrences, correlations between terms and a network of associations between terms.

2.3.3.1 Term occurrences

Text mining of the corpus identified 310 different terms in the definitions of procedural skills. The most frequent used terms were: "skill" (n = 36), "procedure" (n = 28), "procedural" (n = 19), "clinical" (n = 13), "psychomotor" (n = 11) and "patient" (n = 10). The least frequent terms with only one occurrence each were "takes", "theoretical", "derived", "experience", "minimum" and "proficiently". Occurrences of terms are presented in Figure 2.2. To increase visibility only terms which occurred in at least 3 documents are plotted.

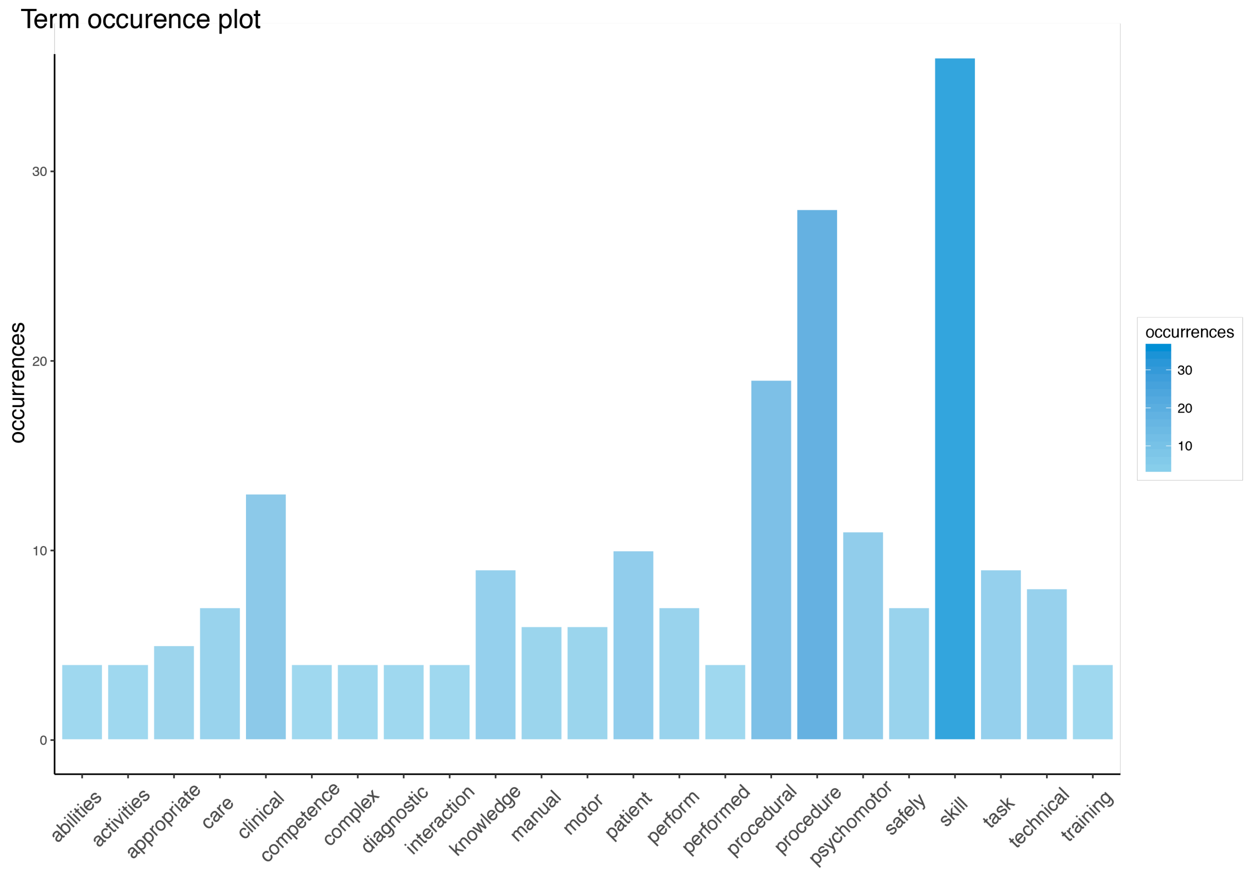


Figure 2.2 Frequent occurring terms in definitions of procedural skills in the document term matrix

2.3.3.2 Correlations

Term occurrences were further investigated by analysing correlations between terms. Correlation in this analysis refers to co-occurrences of terms in definitions (i.e. the appearance of terms is measured in binary form, either the terms appear together in the document term matrix or not, see Table 2.1). To increase clarity only terms with at least five occurrences were included in this analysis. The highest correlations were analysed for the pairs: “task” and “manual” (r = 0.82), “skill and “technical” (r = 0.69), “appropriate” and “motor” (r = 0.67), “psychomotor” and “skill” (r = 0.66) and “motor” and “skill” (r = 0.64). All correlations between frequent occurring terms are plotted in Figure 2.3. Correlations were interpreted as follows: > 0.5 as moderate and > 0.7 as high (Mukaka 2012).

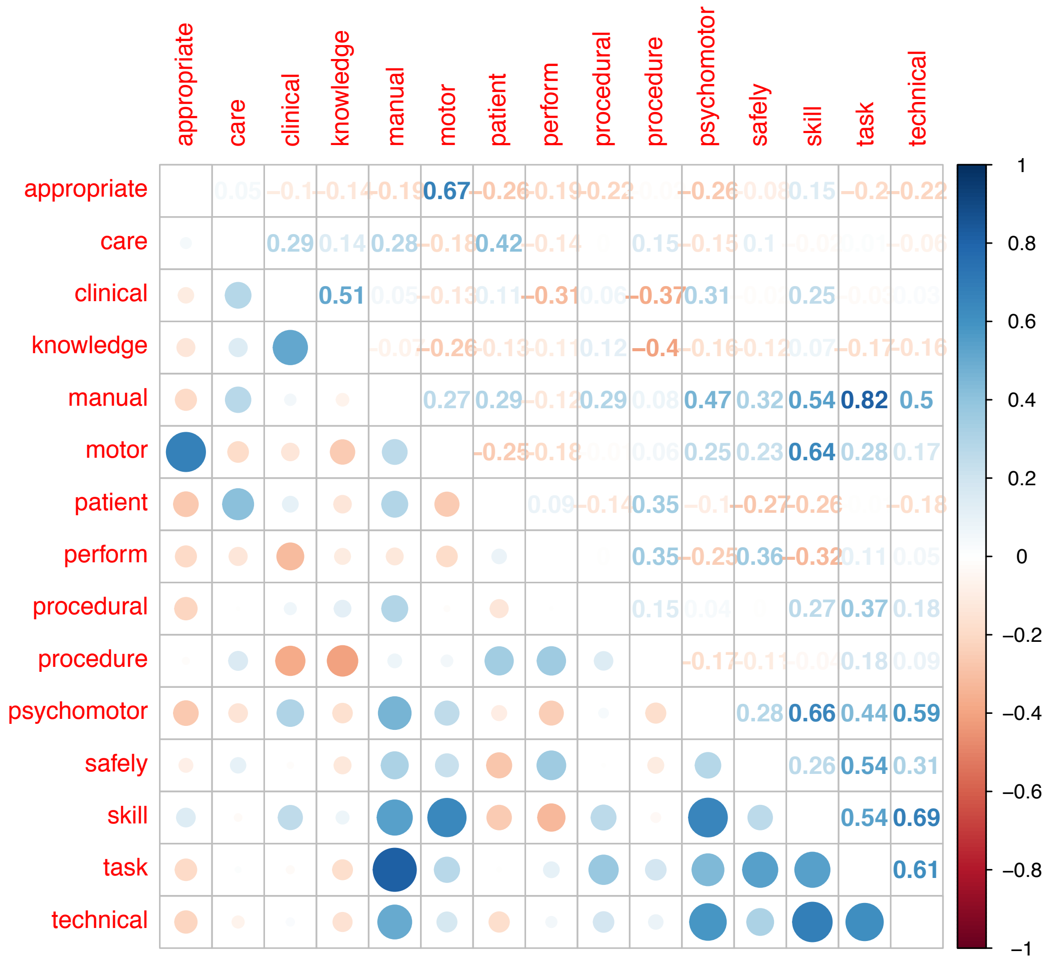


Figure 2.3 Correlations of frequent terms

2.3.3.3 Term association network

A network plot of associated terms was subsequently created (Figure 2.4). To visualise associations, correlations greater than 0.25 were plotted. The threshold of 0.25 was chosen after testing several other thresholds with the aim to create an interpretable network of terms (e.g. a threshold of 0.1 created a chaotic plot, which was not possible to analyse and a threshold of 0.4 did not create a network at all. Instead associated terms remained in small groups, which were not connected to other groups). Within the term association network several highly connected nodes were identified. The most connected terms were: manual (n = 9 links), psychomotor (n = 7 links), skill (n = 8 links) and task (n = 7 links).

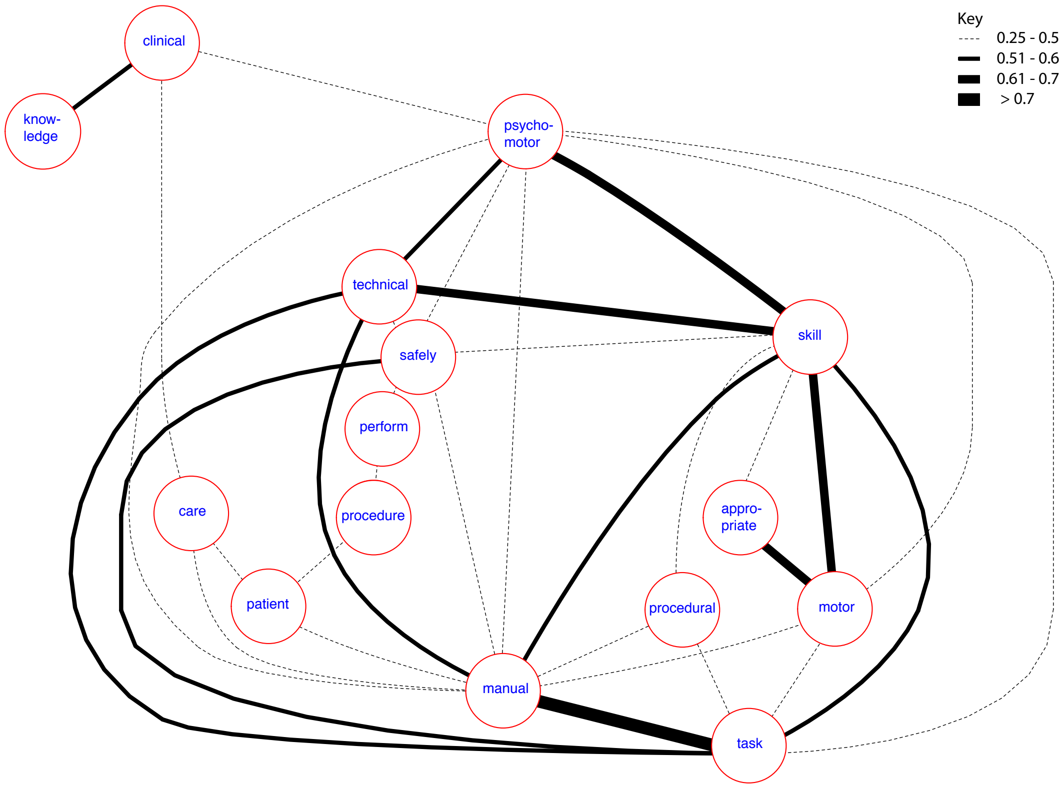


Figure 2.4 Term association network

NB. lines are plotted regarding the strength of the correlation (e.g. dashed for correlation < 0.5)

2.3.3.4 Cluster analysis

Cluster analysis identified two main clusters of definitions. One group consisted of four definitions (Nicholls et al. 2014; Sattelmayer et al. 2016a; The Royal Australian College of General Practitioners 2016; Sattelmayer et al. 2017) the other cluster was considerably bigger with n = 18 definitions (Figure 2.5). The definitions with the smallest distance (highest similarity) to each other were i) Touchie et al. (2013) and Ojha et al. (2015) and ii) Simpson et al. (2002) and Jackson et al. (2009). Nicholls et al. (2014) provided the definition with the greatest distance to other definitions (i.e. to analyse distances each term of the document term matrix can be expressed as having specific coordinates within the matrix. The closer the distance of terms to each other is the smaller the distance)

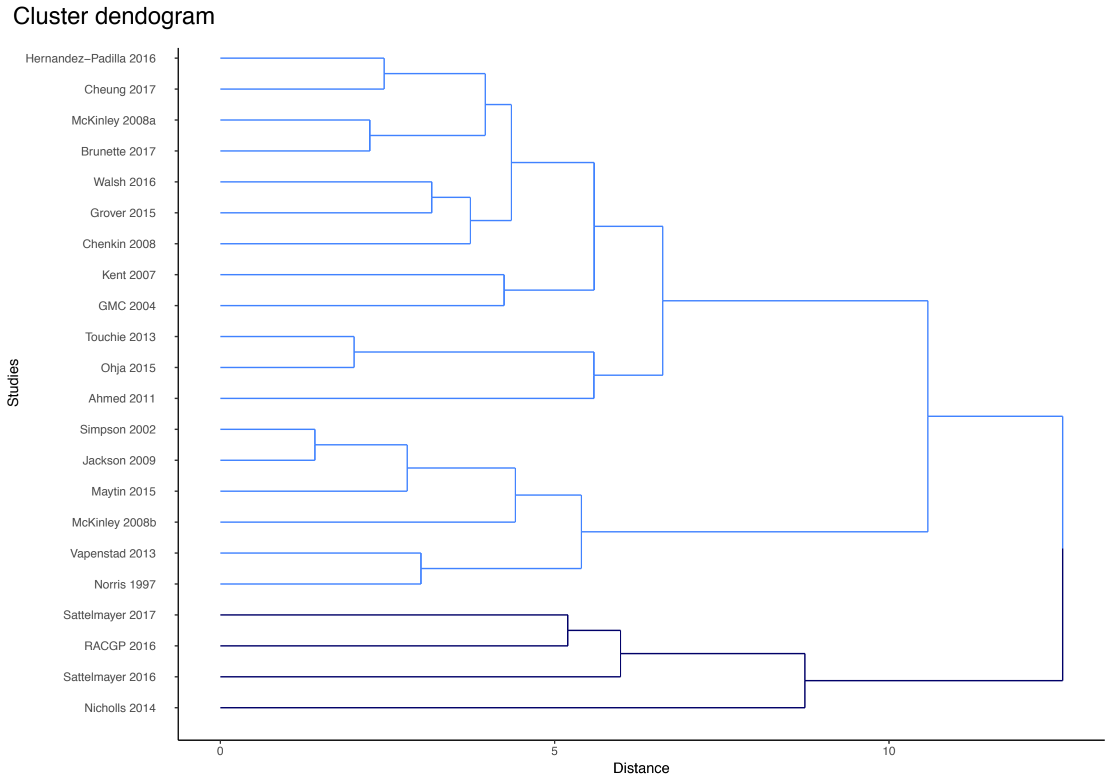


Figure 2.5 Cluster dendogram showing the clustering of 22 definitions of procedural skills based on Euclidian distances.

NB. distances are plotted on the horizontal axis. Similar definitions have a shorter distance to each other compared to dissimilar definitions

2.3.4 A comprehensive definition of procedural skills

The findings of both analyses (i.e. manual coding and text mining) were synthesised to propose a definition and operationalisation of procedural skills in physiotherapy education.

Based on the qualitative and quantitative analysis a comprehensive definition of the concept "procedural skills" was proposed.

> Procedural skills relate to the acquisition of an adequate skill set, that allow the safe application of clinical procedures to patients.

The definition is operationalised in three parts.

The first part of the operationalisation was designed with the help of the quantitative analysis. That is relevant information of frequent occurring terms in definitions of procedural skills and their association as presented in Figure 2.4 were used to operationalise the first part of the definition:

> Procedural skills relate to the acquisition of appropriate motor skills, which allow the safe application of clinical procedures to patients. To adequately perform these skills, knowledge about manual or technical procedures must be acquired.

A second part based on the qualitative analysis of sub-concepts of procedural skills in section 2.3.2.1 was added to the operationalisation:

> Procedural skills may involve decision-making (i.e. selection of appropriate procedures) and communication processes (i.e. communication with the patient about the nature of the procedure). When procedures are actively performed in combination with patients (e.g. procedures in physiotherapy) patient-focussed interaction abilities are required.

A third part of the operationalisation is related to the concepts “clinical skills” and “psychomotor skills”. This part was based on the analysis in section 2.3.2.2:

> The concept of procedural skills is closely related to the concepts of clinical skills and psychomotor skills. However, the first is a more general concept not strictly related to the acquisition of motor skills and the latter is strictly based on the acquisition of motor skills but not only in a clinical setting.

2.4 Discussion - procedural skills definition

Within this chapter definitions of procedural skills in HPE were systematically searched, selected and evaluated. Twenty-two definitions were analysed with the help of text-mining and manual coding. Based on these analyses a comprehensive definition of procedural skills was proposed.

The inclusion of 22 primary articles for the analysis of the concept “procedural skills” represents an adequate sample size. However, not all articles included a comprehensive definition or description of the concept. Some solely provided brief statements about some aspects of procedural skills (e.g.Brunette and Thibodeau-Jarry 2017). In contrast others such as Nicholls et al. (2014) provided considerable information to allow a comprehensive analysis of the concept including related sub-concepts.

Within the pool of included articles two were classified as being influential based on their citations (Simpson et al. 2002; Kent 2007). However, the citations are related to the entire work. Especially, for Kent (2007) this may introduce a bias as the citations refer to "The Oxford Dictionary of Sports Science & Medicine", which covers a variety of other definitions as well.

The work of Simpson and colleagues (2002) relates to the learning outcomes for Scottish doctors. This document contains the whole spectrum of learning outcomes for medical doctors (among others basic clinical sciences and ethical understanding). Practical procedures are only one element of the learning outcomes. Therefore, it cannot be argued that all citing articles refer to procedural skills.

Furthermore, manual coding of integrated sub-concept revealed that both influential works used a relatively low number of sub-concepts within their definition of procedural skills (n = 3). Kent based his definition on the execution of a motor task whereas Simpson and co-workers also used elements of decision-making. Therefore, designing a comprehensive definition using only these two sources was avoided.

2.4.1 Findings of the qualitative analysis

The qualitative analysis revealed one key sub-concept of procedural skills in health professions: "execution of a motor task". This sub-concept was identified in the majority of included articles. It refers to the actual motor performance of a practical procedure. For example, Kent (2007) used the terms "timing" or "frequency" to further explain the sub-concept. Two of the other pre-defined sub-concepts of procedural skills were also frequently incorporated by included authors. These were "knowledge" and "safety".

The sub-concept "knowledge" was used differently among authors. Ten authors used the sub-concept "knowledge" in their definitions of procedural skills. Three authors further elaborated on the sub-concept: McKinley et al. (2008a) stated health-related knowledge should be acquired, Cheung et al. (2017) indicated knowledge as procedural knowledge and the General Medical Council (2004) stressed the importance of awareness of one's knowledge limitations. In contrast, seven authors failed to further define the concept (Chenkin et al. 2008; McKinley et al. 2008b; Vapenstad and Buzink 2013; Nicholls et al. 2014; Grover et al. 2015; Hernandez-Padilla et al. 2016; Walsh 2016).

The sub-concept "safety" received attention by seven authors (Norris et al. 1997; General Medical Council 2004; Nicholls et al. 2014; Maytin et al. 2015; The Royal Australian College of General Practitioners 2016; Walsh 2016; Brunette and Thibodeau-Jarry 2017). Most definitions stated that procedures should be performed safely or patient safety should be guaranteed. However, no statement was found, which considered the safety of health care personnel. But work conditions of personnel performing procedural skills are sometimes poor (e.g. Nyland and Grimmer (2003) report that undergraduate students are often exposed to poor working postures or frequent manual handling positions, which might cause low back pain). Therefore, the safety sub-concept should not be neglected and was integrated in the final definition.

The sub-concepts "decision-making" and "communication" occurred less frequently but due to their clear application both sub-concepts remained in the proposed definition of procedural skills. Decision-making relates to the selection of an appropriate procedure. Violation of this sub-concept may result in the ineffectiveness of the whole procedural intervention and may impact on the safety of the patient.

Communication in this report considers that the health care professional provides essential information about the procedure to the patient. This sub-concept was integrated because not providing this information would violate ethical principles (such as informed consent). However, the communication sub-concept is different from communication skills in general (i.e. it is not related to acquire skills such as patient-centred interview techniques as one element of basic communication skills in medical education (Levinson and Roter 1993)).

The predefined sub-concepts “preparation” and “comfort” were only rarely cited in the included studies. Both sub-concepts may contain relevant information, but it might not be necessary to include both into a definition of procedural skills. However, they might be relevant sub-concepts for the acquisition and assessment of procedural skills.

The qualitative analysis revealed one sub-concept of procedural skills, which is especially useful in the context of physiotherapy education. With “patient-focussed interaction abilities” the integration of the patient into the acquisition of procedural skills is emphasised. As most procedures in physiotherapy education require that the physiotherapist must interact with the patient, this sub-concept was integrated in the final definition.

2.4.2 Findings of the quantitative analysis

The most frequently occurring terms were “skills”, “procedure”, “procedural”, “psychomotor” and “clinical”. Indicating that clinical skills and psychomotor skills are closely related to procedural skills. This was further supported by the analysis of similarity between the three concepts in the included definitions. Therefore, clinical skills may be regarded as a general set of skills, which are used by professionals in their specific health-related context. These clinical skills are not restricted to the execution of motor tasks but include other skills as well (e.g. performing a patient-centred interview). The second concept “psychomotor skills” were appraised as performing a motor task. They differ from “procedural skills” because they are not restricted to motor tasks in a clinical setting. For example, throwing a ball may be classified as a psychomotor skill but not as a procedural skill. Therefore, these three concepts were found to share considerable similarity but should not be used interchangeably.

A high correlation was found between the terms “manual” and “task”, which stresses that manual tasks are at the centre of procedural skills. This is especially true from a physiotherapeutic point of view as most procedures are performed manually.
Based on the correlations of terms it was possible to identify a network of terms representing the concept “procedural skills”. This network was used to build a comprehensive definition of “procedural skills” by integrating the central terms of the network (e.g. manual, skill, safe, procedures, knowledge).

2.4.3 Limitations

There are some limitations to this work, inevitable in a piece of rapid pragmatic development. When searching, it was identified that reporting of definitions occurred only in a small number of RCTs. Only 5.3% of all RCT’s provided a definition of procedural skills. Most RCT’s did not evaluate procedural skills in general but targeted a specific procedural skill and therefore the missing definitions might be partly explained. However, the selection process of the systematic reviews revealed that 13.1% of the papers provided a definition. This indicates that key concepts may be better presented in systematic reviews, where clear definitions are integral to the work, compared to randomised controlled trials. Considering that an understanding of concepts is a necessity for scientists and consumers, consistent reporting of key terms and definitions in skill acquisition related papers is desirable in future research.
A limit of the search and selection process was that only one author performed the necessary processes. Performing these processes with two independent researchers might have increased the amount of confidence in the findings. However, due to time and operational constraints this was not possible and the processes were performed in accordance with a priori defined methods.
The criterion to select only articles, which are not protected behind a paywall was justified as follows: restricted access to research is against the principles of the open science movement (e.g. Berlin declaration (2003) which states that that all users worldwide should be granted free right of access to research literature).

Furthermore, there are controversial opinions regarding the use of text mining in subscription based publications. The Open Knowledge Foundation states “the right to read is the right to mine” (Murray-Rust 2012). In contrast, some journals explicitly disallow mining of their content, even if the researcher has institutional access. To solve this controversy the UK recently legalised text mining for non-commercial uses (Intellectual Property Office 2014).

There are situations where articles with closed access must be used in systematic reviews. For example, in reviews about the effectiveness of interventions. Missing articles could potentially lead to recommendations, which might have serious consequences for patient safety or public health. However, this report systematically appraises a concept. A concept is a theoretical construct of an idea. For this report only ideas, which were publicly available were used to support the idea of the open science movement.

Missing potential eligible articles might have resulted in a slightly different definition of procedural skills. However, as the sample size of 22 included articles was sufficient to perform quantitative and qualitative analyses it can be assumed that the main points would have remained.

The choice to include only RCT’s and systematic reviews was based on pragmatic reasoning. That is both types of study designs are requested to provide information about the conceptual background by either the PRISMA (systematic reviews) or the CONSORT statement (RCT’s). Frequently authors are asked to comply to these statements and therefore it was expected that definitions of procedural skills would be identified in studies with these designs. Definitions of procedural skills may have been published in other study designs as well. However, reporting statements for other study designs are more heterogeneous and in some cases less strict. Therefore, it was expected that RCT’s and systematic reviews would be a reliable source of information in contrast to other study designs.

There are some methodological choices, which may need justification: i) during the text mining frequent terms were defined as having an occurrence of 5 or more times in the text corpus. This choice was made after inspection of the text corpus. Using all terms would have led to confusion in interpretation of figures and analyses. For example, plotting term occurrences or correlations for all terms resulted in huge plots where many terms were not visible any more. Therefore, the amount of 5 or more occurrences was set after exploring several thresholds with the aim to increase visibility and clarity, ii) to build a term association network correlations higher than 0.25 were selected as threshold. This threshold was selected based on the same reasoning as mentioned above.

Sometimes a process called “stemming” is used in text mining. By stemming, terms in the corpus are truncated. For example, the terms “procedure”, “procedures” and “procedural” would be grouped together under the stem “procedur”. This has the advantage that stems of common terms are automatically generated within the text mining programme. However, this process can cause a reduced specificity during text mining (Hull 1996). In the example above combining “procedure” and “procedures” might be a reasonable choice. Both terms relate to the same concept. However, “procedural” might be used with a different meaning. Therefore, related terms were manually combined and stemming was avoided.

Lastly, it can be argued that text mining is not able to detect specific exclusions. For example, an author might state in his definition that procedural skills do not include reasoning skills. Based on the analysis of occurrences and correlations between terms it might be possible that “reasoning skills” would have a high number of occurrences and there could be a high correlation between “procedural skills” and “reasoning skills”. To avoid such a bias in the text mining analysis each definition was checked for specific exclusions. However, exclusions only rarely occurred and did not influence the analysis.

2.4.4 Conclusion

This report performed a thorough analysis of articles using the concept “procedural skills”. With the help of text mining and manual coding it was possible to propose a new comprehensive definition of procedural skills in physiotherapy education. As far as is known this is the first systematic analysis of this complex concept. Sub-concepts of procedural skill such as “knowledge”, “decision-making” and “communication” were proposed.

Furthermore, the related concepts “clinical skills” and “psychomotor skills” were explored regarding their similarity and difference with “procedural skills”. The defined concept “procedural skills” (page 25) will be used as a theoretical foundation in this thesis. The next two chapters (chapter 3 and 4) will review selected motor learning principles, which are used in the teaching of procedural skill acquisition in health professions education or motor skill acquisition.

3 Effectiveness of an attentional focus on the acquisition of complex motor skills: a systematic review with meta-analysis and integrated meta-regression

3.1 Introduction - systematic review focus of attention

This chapter presents supporting information in relation to the acquisition of complex motor skills with the help of the motor learning principle "focus of attention" (FoA). The attentional focus motor learning principle was introduced by Wulf and co-workers (Wulf et al. 1998). The principle relates to the idea that the FoA of the learner can be directed either towards the environment or towards one's own body movements. When the "learners focus their attention on the effects of their movements on the environment" (Wulf et al. 2001, p. 1144) an EFA is used. In contrast, "directing the learner's attention to their body movements" (Wulf et al. 2001, p. 1143) is classified as instructing an IFA.

Some studies have reported that a simple change of wording of instructions or feedback can have a substantial impact on the acquisition of motor skills. Especially, when instructions and feedback were designed with an EFA, motor skill acquisition was reported to be increased (Wulf et al. 2010). Increased movement performance was observed in various sports such as dart throwing (Emanuel et al. 2008) or soccer (Wulf et al. 2002). Furthermore, some studies reported that an EFA could be used to increase skill acquisition in different populations. Wulf et al. (2009) reported increased skill acquisition in people with Parkinson disease and Laufer et al. (2007) reported that an EFA could be used in people with ankle sprains.

3.1.1 How an attentional focus might work?

Wulf et al. (2001) proposed the concept of the "constrained action hypothesis" to present a framework why an EFA might have a beneficial effect on motor skill acquisition.

It was suggested within the hypothesis that individuals constrain their motor control systems when movements are regulated consciously. Naturally, automatic motor control processes control skilled movements. Wulf and colleagues suggested that an EFA does not constrain development and refinement of automaticity. Instead the self-organisation of the nervous system is supported by focussing on the effects of movement (McNevin et al. 2003).
In contrast, when an IFA is used interferences with the automatic movement control can arise (e.g. if a runner is instructed to consciously control the ankle movement to increase speed, the automatic control of this skill can be negatively affected).

3.1.2 Effectiveness of Focus of Attention

Two studies with a high influence (based on their citations) were published by Wulf et al. (Wulf et al. 1998; Wulf et al. 1999). Both studies reported that an EFA was effective for acquisition of motor skills on post-acquisition and retention tests for sporting skills in young healthy adults, which indicated that an EFA can affect performance and genuine learning (Table 3.1). The study published in 1998 showed that an EFA was more effective than an IFA on skill acquisition of balance and skiing skills. In 1999 Wulf et al. reported that an EFA was superior to an IFA for the acquisition of a golf motor skill.
Three systematic reviews were identified, which appraised the effectiveness of this motor learning principle on motor skill acquisition. Kakebeeke et al. (2013) reported that in 13 out of 20 studies an EFA was superior to an IFA. Only in one study an IFA was appraised as being superior on motor skill acquisition. The remaining studies were inconclusive or insignificant. These findings were supported by the other two reviews (Peh et al. 2011; Sturmberg et al. 2013).
A major finding from the systematic reviews is that the risk of bias of included studies was moderate to high. Important characteristics such as blinding of outcome assessment or sound allocation concealment occurred in the minority of studies. Furthermore, poor statistical reporting and heterogeneity prevented the authors undertaking a meta-analysis. Therefore, despite the relatively high number of

included participants an estimated effect of the attentional focus is unclear at the moment and individual studies with high methodological quality and clear reporting should be conducted to reduce uncertainty.

Table 3.1 Evidence table focus of attention

Published systematic reviews					
Study	Included studies	Population	Movement skill	Effect	Risk of bias
Peh et al. (2011)	20	Healthy persons (number not available)	Sport specific skills (such as specific tennis, ski, golf, balance, basketball, volleyball or dart skills)	No quantitative summary effect available. Individual studies support the use of an EFA for skill acquisition for goal related motor skills.	Not appraised
Kakebeeke et al. (2013)	20	Healthy persons (n = 725) and patients in rehabilitation settings (n = 68)	Sport specific skills such as in Peh 2011 in addition: arm pointing movements (in persons with stroke), and balance training (in persons with ankle sprains).	No quantitative summary effect available. EFA was superior to IFA in 13 studies. IFA was superior to EFA in 1 study. Remaining studies showed unclear or insignificant results	All included studies had a high risk of bias (evaluated with the Cochrane Risk of Bias tool).
Sturmberg et al. (2013)	7	Persons with musculoskeletal injuries (n = 202)	Balance training (ankle sprain), muscle relaxation (myofascial pain), muscle strengthening (persons with patellofemoral pain)	No quantitative summary effect available. EFA was superior to IFA in 2 studies. The remaining did not directly compare the two modalities	All included studies had a moderate to low quality evaluated with the GRADE system.
Influential studies (i.e. most cited studies in the field)					
Study	Google scholar citations*	Population	Movement skills	Effect	Design
Wulf et al. (1998)	605	Healthy persons (n = 33) students and professionals for experiment 1 and (n = 16) for experiment 2	Experiment 1: Skiing Experiment 2: Balance task	For both motor tasks an EFA was superior to an IFA during practice and on retention tests.	Randomised controlled study
Wulf et al. (1999)	461	Healthy persons (n = 22), students	Golf (hitting golf balls into a circular target)	EFA was superior to an IFA during practice and on retention tests.	Randomised controlled study

EFA: External focus of attention; IFA: Internal focus of attention; * in June 2018

3.1.3 Focus of attention in health professions education

Wulf et al. (2010) have suggested using an EFA to improve learning of procedures in HPE. However, a previously performed review (Sattelmayer et al. 2016a) did not identify any studies evaluating the impact of an attentional focus on learning of procedures in this setting.

In contrast, a large number of studies have investigated the effect on various motor skills. Procedures in HPE share several characteristics with motor skills in sport. However, there exist also considerable dissimilarities between motor skills in sport and procedures in HPE.

A key characteristic of procedures in HPE is that they are performed under real-world circumstances (i.e. they are not performed under artificial laboratory conditions) and they are relatively complex and frequently consist of multiple procedure parts. In contrast, the motor skills studied in attentional foci studies are frequently performed under laboratory conditions and are not performed under real-world circumstances. Furthermore, not all motor skills can be classified as complex and some motor skills only involve a single body segment such as the hand and arm in dart throwing tasks.

As studies with procedures in HPE were not available it was hypothesised that studies using complex and real-world motor skills could potentially indicate whether a specific attentional focus should be used in HPE and if applicable, the findings of the review could be used as reference data for an educational study using this motor learning principle.

3.1.4 Aim

The aim of this systematic review was to evaluate the application of an EFA compared to an IFA on performance and skill acquisition of complex motor skills.

3.2 Methods - systematic review focus of attention

To increase clarity this report was structured using the PRISMA statement (Moher et al. 2009). The methods for this systematic review were elaborated a priori (with defined selection criteria, data extraction and data-analysis methods) and discussed with the supervisory team. The following criteria were set to identify eligible studies for this review.

3.2.1 Criteria for considering studies for this review

3.2.1.1 Types of studies

- Only controlled studies were included in this systematic review (i.e. studies had to compare interventions).
- Systematic reviews were excluded but checked for potential eligible studies.

3.2.1.2 Types of participants and practiced motor skills

- Studies reporting about healthy adults (18 years and older) were included.
- Studies reporting about other participants such as people with a specific disease were excluded.
- Participants in included studies had to be based in HPE or in sport education and trained a specific sport-related movement skill.
- The practiced motor skill needed to be a complex motor skill. Two criteria were set i) the skill should involve more than the movement of one body segment (e.g. dart throwing skills were excluded) and ii) motor skills had to involve an active transport of the body (i.e. movement skills with a stationary body position such as golf putting were excluded). These complexity criteria were used to excluded motor skills that are considerably different from physiotherapeutic procedures.
- Artificial motor skills such as balance training on a platform or skiing on a simulator were excluded.

3.2.1.3 Types of interventions

- Included studies had to compare the effectiveness of an EFA with an IFA. Other comparisons were excluded (such as comparisons of different EFA modalities).

3.2.1.4 Types of outcome measures

- The outcome measures had to measure performance or acquisition of motor skills (e.g. time needed to perform the motor skill or an accuracy index of the performance)

3.2.1.5 Miscellaneous

- Studies had to report enough data to allow an inclusion into a meta-analysis. For continuous outcomes data for means, standard deviations and number of participants within each group were required.
- No restrictions were set with regard to language, publication type (i.e. open or closed access) or year of publication

3.2.2 Search methods for identification of studies

Four electronic databases were searched for eligible studies: Medline (via Pubmed), Embase, Education Resources Information Center (ERIC) and SPORTDiscus. No limits were set regarding language or year of publication. A search string was designed based on three categories (i.e. motor skills, intervention and outcome). Keywords within each category were combined with the Boolean operator "OR". Afterwards, the three categories were combined with the operator "AND". The search string is presented in Table 3.2

Table 3.2 Search strategy

Motor skill	Intervention	Outcome
motor skill OR practical skill OR procedural skill OR complex skill OR motor skill OR motor activity OR motor task OR psychomotor performance	focus of attention OR attentional focus OR attentional foci OR external focus OR external-focus OR internal focus OR internal-focus OR constrained action	performance OR skill acquisition OR movement time OR response time OR reaction time OR acquisition OR retention OR transfer

3.2.3 Study selection

All identified records were imported in an electronic literature management systems (Endnote X7) and duplicates were removed. In a following step one reviewer (MS) screened titles and abstracts of all records. Then the full-texts of the remaining articles were screened by MS and included in the systematic review if all inclusion criteria were met. In addition, the reference lists of included studies were screened for potential eligible studies.

3.2.4 Data extraction

Data extraction was performed by a single reviewer (MS). The following information was collected i) general information about studies and participants (i.e. authors, design, country, population and experience of population); ii) information about interventions (i.e. practiced motor skills, complexity of motor skills, information about the application of the specific EFA and IFA conditions, amount of practice trials in each condition); iii) information about study endpoints (i.e. scheduled endpoints and administered outcome measures) and iv) statistical data necessary to perform a meta-analysis (i.e. for each group means and standard deviations for all possible endpoints were extracted. If not available data was visually extracted from figures or imputed from available data. For example, standard errors were used to calculate missing standard deviations. All imputations were based on guidelines presented in the Cochrane Handbook of Interventions (Higgins et al. 2008)).

3.2.5 Data analysis

Two statistical methods were applied to analyse data in this review. First, effectiveness of the interventions was evaluated with a meta-analysis and second, the influence of potential moderator variables was explored with meta-regression.

3.2.5.1 Meta-analysis

In a first step, means and standard deviations were used to calculate summary statistics for each included study. When possible final values were used. If final values were not available change from baseline values were used. To summarise the study effect Standardized Mean Differences (SMD) were calculated as effect sizes (studies used a variety of outcome measures due to different included motor skills). The individual study effects were then combined and a pooled summary effect over all studies was estimated. A random effects model was chosen for the meta-analysis in Review manager 5.3. Effect sizes were interpreted with the help of Cohen (1992). Values below 0.2 were considered as small effect. Values between 0.5 as moderate and values over 0.8 were classified as a large effect. To classify statistical heterogeneity I^2 values were interpreted following the guidelines presented by Higgins and Thompson (2002) and Higgins et al. (2008). Therefore, four categories of heterogeneity were used: i) considerable heterogeneity (100% - 75%); ii) substantial heterogeneity (90% - 50%); iii) moderate heterogeneity (60% - 30%) and iv) possibly not important heterogeneity (0% - 40%).

3.2.5.2 Meta-regression

The effects of two potential moderator variables were explored with meta-regression. These were previous experience with the practiced motor skill and complexity of the practiced motor skill. For both variables evidence is available that skill acquisition differs between sub-groups. For example, Guadagnoli and Lee (2004) differentiate between various experience levels (e.g. novices or experts) to predict a specific performance level. Wulf and Shea (2002) argue that valid principles identified for the skill acquisition of non-complex skills do not generalise complex skill learning. To explore how the two potential moderator variables might influence the size of the intervention effect a mixed effects meta-regression was performed in the statistical package R (version 3.4) with the "metafor" package (Viechtbauer 2010). The moderator variables (complexity or experience) were set as independent variables and the effect estimate (SMD) of the meta-analysis was used as dependent variable.

3.2.6 Risk of bias evaluation

Risk of bias of the included studies was evaluated with the Cochrane Risk of Bias tool (Higgins et al. 2011). The assessment evaluated the following risk of bias items: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting and others bias. One reviewer (MS) evaluated the risk of bias of each item. Each item was awarded either a low risk of bias, an unclear risk of bias or a high risk of bias.

3.3 Results - systematic review focus of attention

This section is structured within three sections. First, results of the search are presented. Then, findings regarding effectiveness of the interventions are analysed and last, the risk of bias evaluation of the included studies is presented.

3.3.1 Results of the search

The search on electronic databases identified 1,426 records (Figure 3.1). One additional record was identified through record checking of included studies. After deletion of duplicates the titles and abstracts of 1,370 record were screened. This led to the exclusion of 1,251 records. The remaining 119 full-text articles were evaluated and 111 were excluded. Reasons for exclusion were i) artificial motor skills (e.g. skiing on simulators) were practiced (n = 42); ii) practiced motor skills were not rated as complex (n = 18); iii) the studies did not compare an EFA intervention against an IFA intervention (n = 15); iv) studies did not use a control group or control intervention in their design (n = 10); v) other participants than healthy adults were included (n = 20) and vi) studies did not provide enough data to allow a statistical analysis (n = 6).

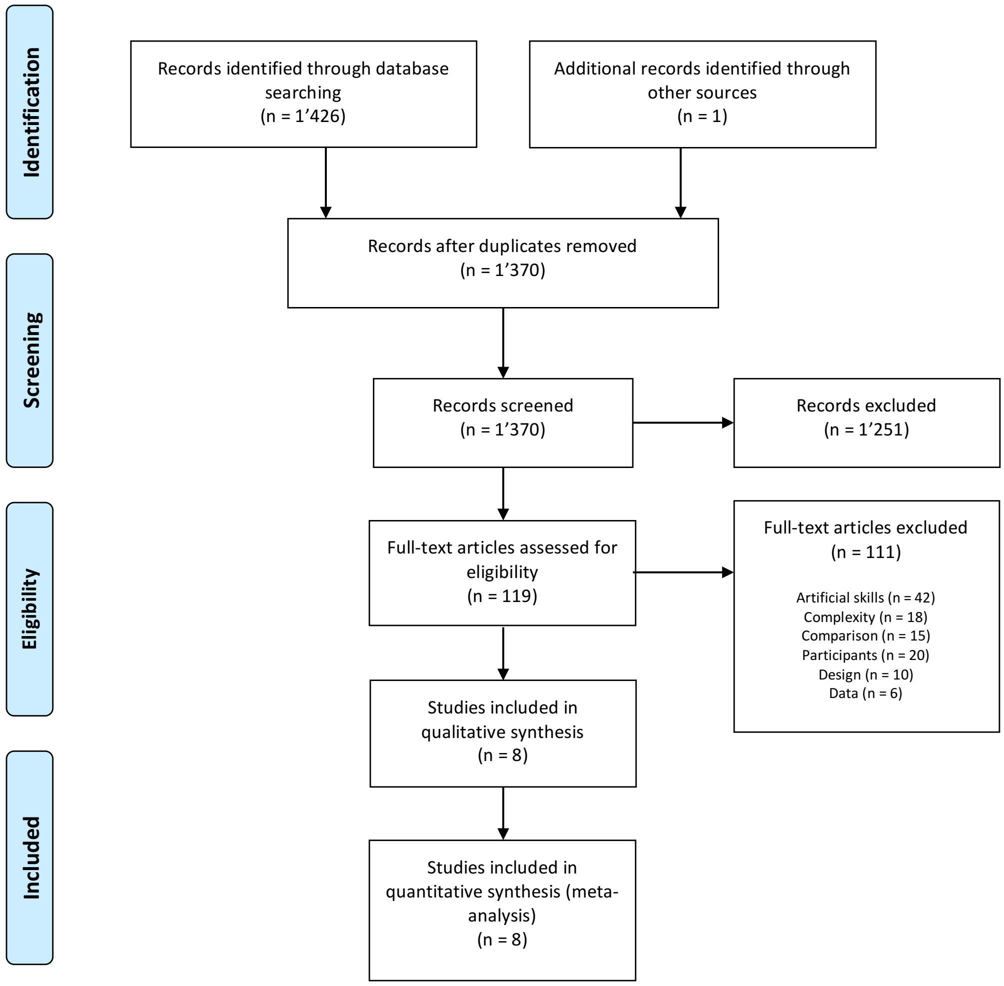


Figure 3.1 PRISMA flow diagram

3.3.1.1 Study characteristics included studies

After the selection process eight studies with a total of 277 participants were included in this systematic review. All included studies compared the effectiveness of an EFA intervention against an IFA intervention on the performance of various motor skills. The practiced motor skills in the studies were: sprinting, either 10 or 20 metres (Ille et al. 2013; Porter et al. 2015); table tennis (Koedijker et al. 2007); a gymnastic dance routine (Lawrence et al. 2011); shot put (Makaruk et al. 2013); throwing (Southard 2011); basketball (Zachry et al. 2005) and discus throwing (Zarghami et al. 2012). All studies compared an EFA against an IFA intervention but different study designs were chosen. Four studies randomised participants to an EFA or IFA intervention (Koedijker et al. 2007; Lawrence et al. 2011; Southard 2011; Makaruk et al. 2013). The remaining studies did not use a randomised control study design. In these studies a cross-over design without randomisation was used (i.e. participants performed the motor skill under EFA and IFA instructions). Performance of motor skills was measured at different study endpoints. All studies administered an acquisition (performance during the acquisition phase) or post-acquisition endpoint (i.e. measurement of performance immediately after the acquisition period). Only two studies used retention-tests in their study design (Lawrence et al. 2011; Southard 2011). In both studies participants were re-assessed one week after the acquisition phase. A transfer test was performed in the study of Lawrence et al. (2011). The following outcome measures were used: two studies measured the throwing distance (Zarghami et al. 2012; Makaruk et al. 2013). The time needed to sprint or run was measured in two studies (Ille et al. 2013; Porter et al. 2015), Koedijker et al. (2007) measured performance with a combined accuracy and movement execution score, Southard (2011) assessed a throwing performance with peak angular velocities and Lawrence et al. (2011) used the Fédération Internationale de Gymnastique Code in their study.

The use of the FoA instructions varied between studies. Some studies provided very brief instructions (e.g. Makaruk et al. 2013), while others designed complex instructions with several elements (e.g. Southard 2011). The amount of practice trials within the acquisition phase varied considerable between studies ranging from 3 trials (Porter et al. 2015) to 450 trials (Koedijker et al. 2007). Further diversity was analysed regarding the amount of previous experience and complexity of the practiced motor skills. Both variables were further investigated in separate sections of this report. Key characteristics of included studies are presented in Table 3.3.

Table 3.3 Characteristics of included studies

Author	Design, country	Population	Motor skill	Experience	Intervention (EFA)	Intervention (IFA)	Acquisition and end-points	Outcome (measures)	Findings (values at a specific endpoint)
Ille et al. (2013)	Cross over study, France	N = 16 years mean age range: 20 - 30 years	Sprint start performance	N = 8 experts N = 8 novices	"Get off the starting blocks as quickly as possible, head towards the finish line rapidly and cross it as soon as possible"	"Push quickly on your legs and keep going as fast as possible while swinging both arms back and forth and raising rapidly your knees"	Acquisition: each condition (i.e. EFA, IFA and control was practiced 5 times). Rest period between conditions was 2 days.	Time needed to finish, reaction time, block clearance time, running time	Acquisition EFA novices: mean 2.33 seconds (SD: 0.10) IFA novices: mean 2.44 seconds (SD: 0.10) EFA experts: mean 2.18 seconds (SD: 0.08) IFA experts: mean 2.25 seconds (SD: 0.06)
Koedijker et al. (2007)	RCT, Netherlands (4 groups explicit learning, implicit learning, environmental focus learning and movement focus learning)	N = 34 mean age: 21.8 years SD: 3.58	Table tennis forehand with the aim to hit a target on the other side of the table	Novices, little or no prior experience	Attention was focussed on the ball.	Attention was focussed on movement of the body (i.e. arm, trunk, elbow and feet)	Acquisition 9 blocks of 50 trials, post-acquisition test with 50 trials (i.e. low-pressure test)	Combined score of accuracy (i.e. distance to target) and movement execution (e.g. movement quality of forehand execution)	Post-acquisition EFA mean 2.55 (SD: 0.98) IFA mean 2.63 (SD: 0.83)
Lawrence et al. (2011)	RCT (4 groups: EFA, IFA, internal	N = 40 (mean age: 20.3	Gymnastic routine	No previous experience	Instructions were constructed according	Participants were instructed to focus on exerting an equal force on their	Acquisition: (40 trials), retention: (1	Fédération Internationale de	Post-acquisition EFA mean 7.69 (SD: n.a.)

	irrelevant and control)	years, SD: 1.6)			to Wulf's (2007) and Gentile's (2000) suggestions. Participants in the external focus group were instructed to focus on their movement pathway as well as to exert an even pressure onto the support surface	feet, keeping their arms out straight, level with their shoulders. Two reinforcing focus questions were asked: "Were your arms level with your shoulders during the previous performance" and "did you exert an equal force on your feet".	week afterwards, 5 trials), transfer test (same as retention)	Gymnastique Code	IFA mean 7.58 (SD: n.a.) Retention EFA mean 7.88 (SD: 0.32) IFA mean 7.60 (SD: 0.24) Transfer EFA: 7.78 (SD: 0.27) IFA: 7.53 (SD: 0.24)
Makaruk et al. (2013)	Cross over study (3 groups: EFA, IFA and control), Poland	N = 30 (mean age: 22.4 years, SD: 2.4)	Shot put; two motor skills were trained underhand and overhead shot put.	Experts with several years of experience	Participants received the following instructions: "When you are putting the shot, focus on hitting the visible target."	Participants received the following instructions: "When you are putting the shot, focus on extending your arms rapidly."	Acquisition: 30 trials, 15 trials for the overhead and 15 trials for the underhand shot put	Throwing distance	Acquisition Overhead shot-put distance EFA mean 21.05 metres (SD: 1.68) IFA mean 20.7 metres (SD: 1.51)
Porter et al. (2015)	Cross over study, USA 3 conditions: EFA, IFA and control	N = 84 undergraduate college students (mean age: 20.17 years, SD: 1.53)	Short distance sprint (20-metre maximal effort dash sprint)	Low skilled, untrained volunteers	Participants were instructed to focus on the results of their sprinting movement (e.g." … while clawing the floor with shoe …").	Participants were instructed to focus on their sprinting technique (e.g. "… moving your leg and foot down and back as quick as possible …").	Acquisition: 3 trials for each condition over 3 consecutive days.	Time needed to sprint 20m	Acquisition EFA mean 21.05 seconds (SD: 1.68) IFA mean 20.7 seconds (SD: 1.51)

Southard (2011) experiment 1	RCT, USA, 6 conditions (EFA, IFA, velocity control, EFA velocity, IFA velocity)	N = 39 university students	Throwing with the non-preferred arm	Novices, participants with mature throwing pattern were excluded	The following set of instructions was provided: i) when throwing, turn and face the wall; (ii) shift your weight toward the front mat; and iii) use your entire body like a whip, like a horseman driving his horses.	The following set of instructions was provided: i) when throwing, rotate your left shoulder back; ii) shift your weight toward your front leg; and iii) accelerate your trunk first, then your shoulder, upper arm, lower arm, and hand	Acquisition: 6 practice sessions each consisting of 15 trials i.e. 90 trials Retention: 15 trials one week later	Elbow lag and wrist lag (peak velocity of distal joint compared to the neighbouring proximal joint)	Post-acquisition EFA mean 25.5 (SD: 6.73) IFA mean 16.99 (SD: 6.71) Retention EFA mean 18.25 (SD: 13.08) IFA mean 12 (SD: 9.66)
Zachry et al. (2005)	Cross-over study, USA (no randomisation)	N = 14 university students (mean age: 26.2 years)	Basketball free throw	Skilled participants with at least 1 year of experience	For the external focus condition, they were instructed to concentrate on the centre of the rear of the basketball hoop	For the internal focus condition, participants were instructed to concentrate on the “snapping” motion of their wrist during the follow-through of the free throw shot	Acquisition: 40 trials, 20 IFA and 20 EFA	Performance: Accuracy of shot, EMG measures	Acquisition Accuracy EFA mean 2.56 (SD: 0.41) IFA mean 2.09 (SD: 0.4)
Zarghami et al. (2012)	Cross-over study, Iran (no randomisation)	N= 20 undergraduate male university students, mean age: 22 years, SD: 1.58	Discus throwing	All participants had some previous experience with discus throwing	Participants were told to throw as far as possible while focussing on the landing location of the discus	Participants were instructed to throw as far as possible while concentrating on their hand and wrist	Warm-up: 5 trails; Acquisition: 5 trials under each condition	Performance: throwing distance	Acquisition EFA mean 20.48 metres (SD: 1.26) IFA mean 19.35 metres (SD: 1.24)

EFA: External focus of attention; IFA: Internal focus of attention, SD: standard deviation

3.3.2 Findings effectiveness

This section presents evidence regarding the effectiveness of EFA- versus IFA-interventions at (post-) acquisition, retention and transfer tests. Furthermore, the influence of two moderator variables were explored with meta-regression.

3.3.2.1 Acquisition and post-acquisition tests

Seven studies reporting eight samples with 356 observations could be included for the analysis of performance at (post-) acquisition tests. Two studies (Ille et al. 2013; Porter et al. 2015) practiced a running motor skill (i.e. 10 and 20 metre sprint). Five studies practiced skills where participants had to manipulate objects. These were table tennis (Koedijker et al. 2007), overhead shot put (Makaruk et al. 2013), throwing (Southard 2011), basketball free shot (Zachry et al. 2005) and discus throwing (Zarghami et al. 2012). Performance measures differed between the included studies. Running was assessed with the time needed to finish. Table tennis performance was assessed with a combination score of i) accuracy to hit a target and ii) quality of movement assessed on video recordings. The distance in metres was used as measurement instrument for the shot put and discus throwing performance. To evaluate the throwing performance, the wrist lag was recorded (i.e. peak velocity from the distal joint compared to the proximal joint). Basketball performance was assessed with the accuracy of the free throw.

The meta-analysis showed a moderate effect in favour of an EFA (SMD: -0.54; 95% CI between -0.86 and -0.22). This finding was statistically significant. Statistical heterogeneity for this analysis was low to moderate I^2: 39% (Figure 3.2).

	EFA			IFA				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Ille 2013	2.18	0.08	8	2.25	0.06	8	7.4%	-0.94 [-1.98, 0.11]
Ille 2013	2.33	0.1	8	2.44	0.1	8	7.3%	-1.04 [-2.10, 0.02]
Koedijker 2007	-2.55	0.98	9	-2.63	0.83	9	9.0%	0.08 [-0.84, 1.01]
Makaruk 2013	-21.05	1.68	30	-20.7	1.51	30	18.9%	-0.22 [-0.72, 0.29]
Porter 2015	3.75	0.44	84	3.87	0.63	84	27.1%	-0.22 [-0.52, 0.08]
Southard 2011	-25.2	6.73	5	-16.99	6.71	5	4.7%	-1.10 [-2.49, 0.28]
Zachry 2005	-2.56	0.41	14	-2.09	0.4	14	11.0%	-1.13 [-1.93, -0.32]
Zarghami 2012	-20.48	1.26	20	-19.35	1.24	20	14.5%	-0.89 [-1.54, -0.23]
Total (95% CI)			178			178	100.0%	-0.54 [-0.86, -0.22]

Heterogeneity: Tau² = 0.08; Chi² = 11.51, df = 7 (P = 0.12); I² = 39%
Test for overall effect: Z = 3.30 (P = 0.0010)

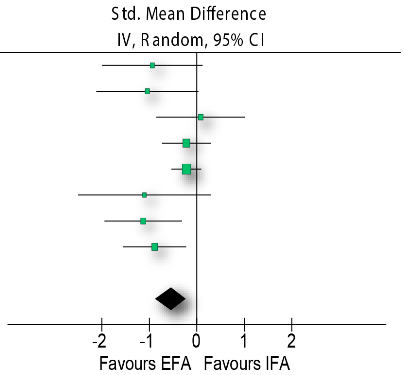


Figure 3.2 Forest plot EFA versus IFA at acquisition and post-acquisition tests

3.3.2.2 Retention and transfer tests

Two studies were included in the analysis of performance at retention tests (Lawrence et al. 2011; Southard 2011). In total, a sample size of 30 participants could be analysed. The retention tests were scheduled one week after the post-acquisition tests. Trained motor skills between the two studies differed. Lawrence and colleagues (2011) practiced a dancing routine and measured performance of the dancing routine with the “Fédération Internationale de Gymnastique Code of Points for artistic gymnastics”. Southard et al. (2011) trained a throwing motor skills and performance was measured using biomechanical parameters (i.e. wrist lag) of the throwing performance. The analysis showed a very large effect size of -1.44 SMD (95%CI between -2.77 and -0.11) in favour of an EFA. The effect was statistically significant with a p-value of 0.03 and statistical heterogeneity was moderate (I^2: 46%). A forest plot of the analysis is presented in Figure 3.3.

One study administered a transfer test (Lawrence et al. 2011). Therefore, pooling of multiple studies was not possible for this endpoint and relative few participants (n = 20) were included in the analysis. During the transfer test the participants performed the same gymnastic motor skill as practiced in the acquisition phase but had to use the opposite foot and arm movements. The analysis showed a large effect size (SMD: -0.94; 95%CI: -1.87 to -0.00) in favour of an EFA. The analysis did not reach the level of significance and the p-value did not cross the 0.05 threshold (Figure 3.3).

	EFA			IFA				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Retention test								
Lawrence 2011	-7.88	0.32	10	-7.6	0.24	10	65.6%	-0.95 [-1.88, -0.01]
Southard 2011	-18.25	13.08	5	12	9.66	5	34.4%	-2.38 [-4.20, -0.55]
Subtotal (95% CI)			15			15	100.0%	-1.44 [-2.77, -0.11]
Heterogeneity: Tau² = 0.47; Chi² = 1.86, df = 1 (P = 0.17); I² = 46%								
Test for overall effect: Z = 2.12 (P = 0.03)								
Transfer test								
Lawrence 2011	-7.78	0.27	10	-7.53	0.24	10	100.0%	-0.94 [-1.87, -0.00]
Heterogeneity: Not applicable								
Test for overall effect: Z = 1.97 (P = 0.05)								

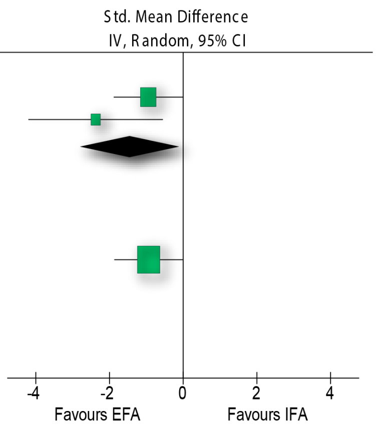


Figure 3.3 Forest plot EFA versus IFA at retention and transfer tests

3.3.2.3 Meta-regression motor skill complexity

To analyse whether skill complexity is an important variable for the decision to use or not to use a specific FoA, each skill was appraised and classified according to its complexity with the framework of Gentile (2000), which is a 4x4 level taxonomy with lower alphanumerical scores representing less complex tasks in terms of movement complexity and stable environments (Appendix ii). In Table 3.4 all motor skills and their corresponding complexity are presented.

Table 3.4 Complexity of practiced motor skills classified with Gentile's framework

Study	Motor skill	Regulatory conditions	Intertrial variability	Use of objects	Body orientation	Rating
Ille et al. (2013)	Sprint	Stationary	Absent	Absent	Transport	1C (3)
Koedijker et al. (2007)	Table tennis	In-motion	Absent	Present	Transport	3D (12)
Lawrence et al. (2011)	Gymnastic routine	In-motion	Absent	Absent	Transport	3C (11)
Makaruk et al. (2013)	Shot put	Stationary	Absent	Present	Transport	1D (4)
Porter et al. (2015)	Sprint	Stationary	Absent	Absent	Transport	1C (3)
Southard (2011)	Throwing	Stationary	Absent	Present	Transport	1D (4)
Zachry et al. (2005)	Basketball	Stationary	Absent	Present	Transport	1D (4)
Zarghami et al. (2012)	Discus throwing	Stationary	Absent	Present	Transport	1D (4)

Skill complexity ranged between a classification of 1C scored as 3 and 3D scored as 12. Six skills were classified within level 1 of Gentile's taxonomy. The remaining two motor skills were appraised as representing level 3 skills. Both studies (Koedijker et al. 2007; Lawrence et al. 2011) were appraised as having in motion regulatory conditions. Within the study of Koedijker et al. (2007) the participants had to react on table tennis balls provided by a ball machine. The gymnastic routines in the study of Lawrence et al. (2011) were performed on soft surfaces.

To analyse whether skill complexity was associated with the performance at the post-acquisition test a meta-regression was performed. Skill complexity was set as independent predictor and performance at the post-acquisition test (i.e. effect size) was used as dependent variable. The regression coefficient for skill complexity b1: 0.07 (95% CI between -0.09 and 0.23) predicted a positive relationship between skill complexity and performance at the post-acquisition endpoint (Figure 3.4). Less complex motor skills seemed to benefit more from an EFA compared to more complex motor skills. An increase of one unit on Gentile's complexity framework increased the relative effectiveness of an IFA against an EFA of about 0.07 SMD's. However, the analysis did not reach the level of statistical significance (p-value: 0.39).

Equal effectiveness between EFA and IFA was seen at a complexity level of 3D (12) (i.e. the point where the regression line and the line of equal effectiveness crossed). Not enough data were available for a meta-regression of the retention and transfer test endpoints.

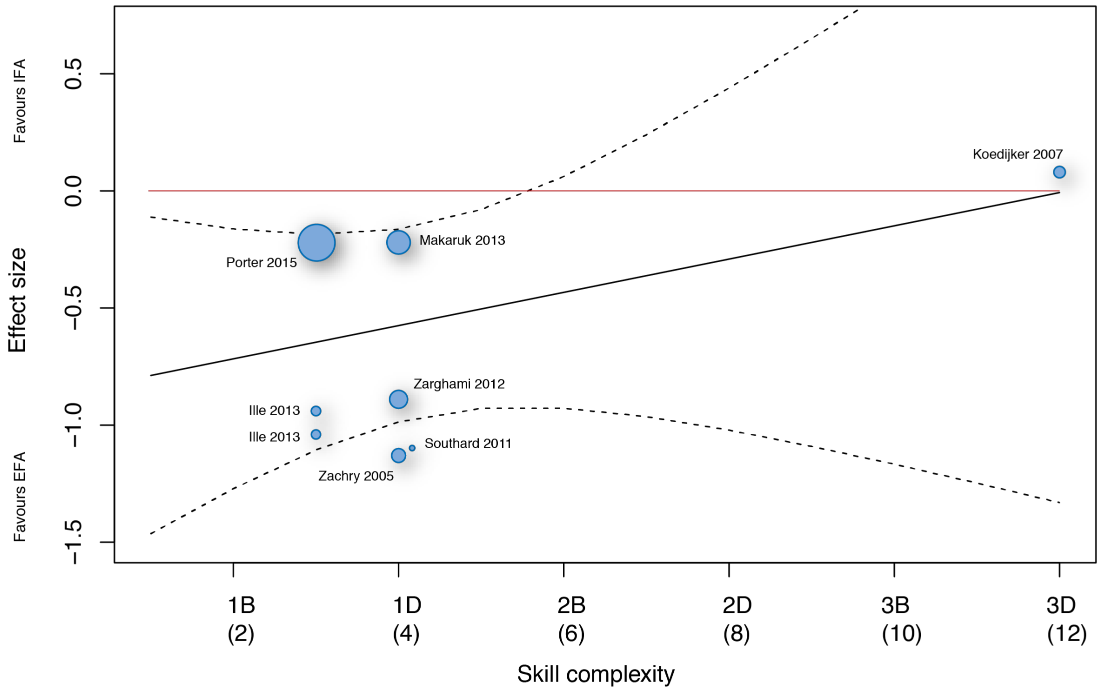


Figure 3.4 Bubble plot for meta-regression of post-acquisition test data with motor skill complexity as independent predictor.

NB. The red line represents the line of equal effectiveness between EFA and IFA. The predicted regression line is plotted in black with corresponding confidence intervals.

3.3.2.4 Meta-regression previous experience with the motor skill

This section relates to a meta-regression of participant's previous experience with the practiced motor skills and performance at the post-acquisition test. First, participant's experience was classified between 0 (no experience) and 3 (expert experience). A score of 1 was given if participants had some previous experience and a score of 2 was provided when participants did have considerable experience with the practiced motor skill. The experience level for each study is presented in Table 3.5.

Table 3.5 Experience of the study participants with the practiced motor skills

Study	Experience	Motor skill	Experience level
Ille et al. (2013)	Experts	Sprint	3
Ille et al. (2013)	Novices	Sprint	0
Koedijker et al. (2007)	Little or no experience	Table tennis	1
Lawrence et al. (2011)	No experience	Gymnastics	0
Makaruk et al. (2013)	Experts	Shot put	3
Porter et al. (2015)	Low skilled	Sprint	1
Southard (2011)	Low skilled	Throwing	1
Zachry et al. (2005)	1 year of experience	Basketball	2
Zarghami et al. (2012)	Some experience	Discus throwing	1

For the meta-regression, the experience of the participants was used as independent predictor and the performance at the post-acquisition test (i.e. effect size) was set as dependent variable. The analysis showed a regression coefficient b1 of 0.03 with a 95% CI between -0.39 and 0.46. The analysis was not statistically significant (p-value: 0.89). Figure 3.5 presents a bubble plot of the meta-regression. Due to the low regression coefficient, the regression line is nearly horizontal indicating that novices and experts equally benefited from an EFA.

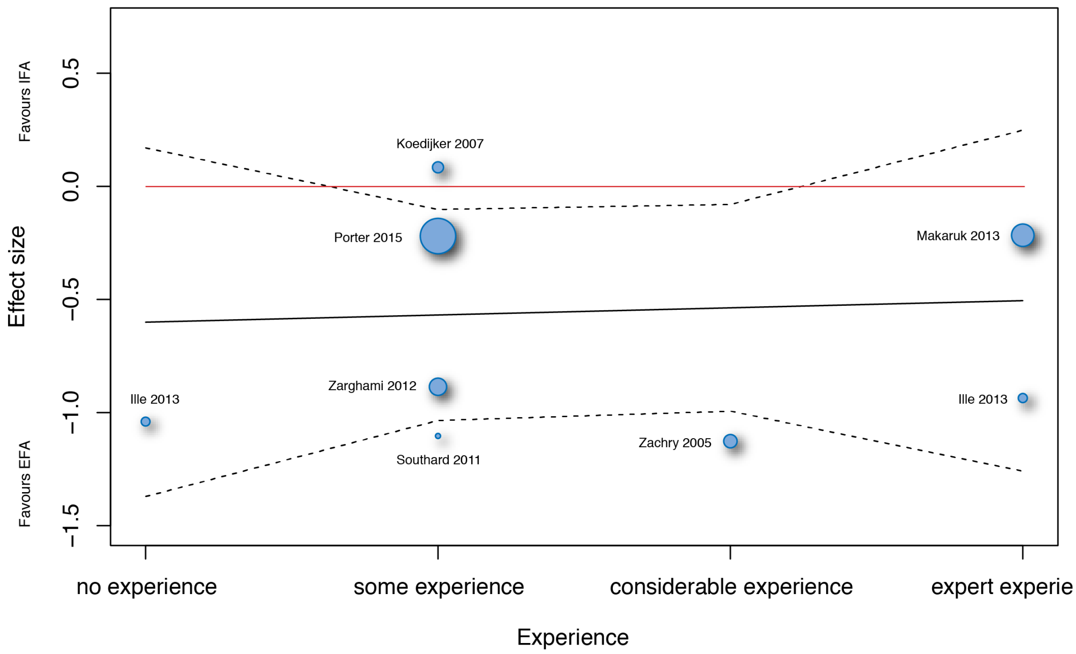


Figure 3.5 Bubble plot for meta-regression of post-acquisition test data with previous experience as independent predictor

NB. The red line represents the line of equal effectiveness between EFA and IFA. The predicted regression line is plotted in black with corresponding confidence intervals

3.3.3 Risk of bias

All included studies were appraised as having had at least one item of the Cochrane risk of Bias tool scored a high risk of bias. All studies received a high risk of bias evaluation on the item “Blinding of participants and personnel” because the personnel instructing the intervention was not blind. This is a common issue in rehabilitation research and instructed intervention trials because double blinding is very difficult to achieve. Four studies were classified as presenting a high risk on three risk of bias items (Zachry et al. 2005; Zarghami et al. 2012; Ille et al. 2013; Porter et al. 2015). This was caused because participants were not randomised into different groups. A low risk of bias on the item “Blinding of outcome assessment” was rated when independent observers were used (Koedijker et al. 2007; Lawrence et al. 2011) or when the performance was measured with the help of automatic devices (e.g. timing machines for the sprint performance) (Southard 2011; Ille et al. 2013; Porter et al. 2015). Some studies received an unclear bias rating in the category “Other bias”. This rating was awarded when participants practiced a motor

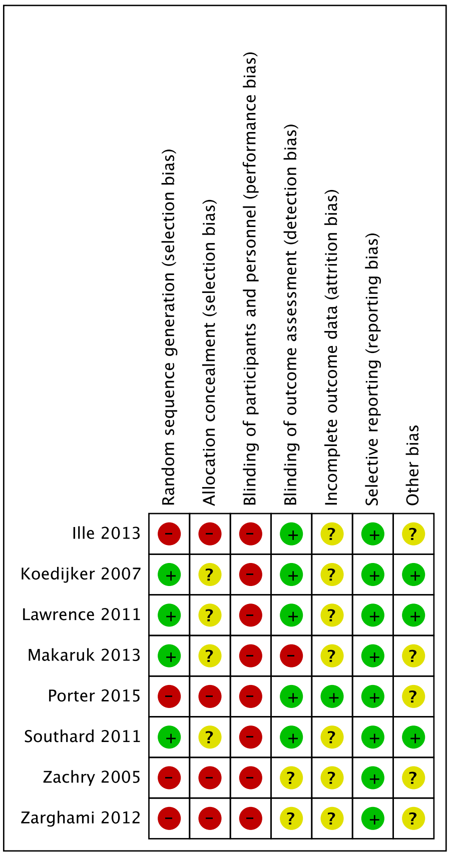


Figure 3.6 Risk of bias evaluation of included studies

skill under both conditions (EFA and IFA) and the time interval of the wash out period between the two practice conditions was either not stated or not justified (Figure 3.6).

3.4 Discussion - systematic review focus of attention

This systematic review set out to explore the effectiveness of FoA on skill acquisition of complex real-world motor skills. Based on the searched literature this is the first report performing a meta-analysis and meta-regression for this intervention. The main findings of this study were i) the performance at post-acquisition was significant higher in the EFA group with a moderate effect size and findings of the analysis of the retention test showed that the effect in favour of an EFA was constant over time. The effect was large and statistically significant. Furthermore, analysis of the transfer test indicated that the ability of the EFA group to apply the acquired skill to a novel task was superior compared to the IFA group; ii) meta-regression of the included studies identified the potential relevant variable “skill complexity”, which could predict the effectiveness of the FoA. Less complex motor skills seemed to benefit more from an EFA compared to more complex motor skills. An increase of one unit on Gentile's complexity framework increased the relative effectiveness of an IFA against an EFA of about 0.07 SMD's. This analysis might have important consequence for the decision when to use an EFA or IFA. For most motor skills with a low to moderate rating on Gentile's framework (2000) an EFA seems to be the appropriate choice. In contrast, complex and highly complex motor skills might benefit more from an IFA. However, the meta-regression was not statistically significant. There were insufficient studies available practicing highly complex skills. Future studies should set out to explore the effectiveness of an FoA on highly complex skills.

The exploration of the second potential relevant moderator variable "previous experience" showed that learners with different levels of previous experience benefitted equally from an EFA. This indicates that the appropriate FoA can be applied to a range of different learners starting from "novices" over "some experience" to "expert experience".

3.4.1 Quality of the evidence

The findings of this study should be analysed with caution because the overall risk of bias was considerable. First, a selection bias might have occurred. Only 50% of the included studies were appraised as having a low risk of bias on "sequence generation". Furthermore, reporting of the item "allocation concealment" was unclear or rated as high risk in all studies. Adequate performance of both items is possible with a relatively low amount of resources and reporting of these items should be performed with more caution in future studies. A performance bias measured with the item "blinding of participants and personnel" is also possible within the current analysis. While it is theoretically possible to blind the participants to the FoA it is nearly impossible to blind the personnel providing the instructions or feedback. Therefore, future studies might not be able to decrease this source of bias. However, a detection bias can be avoided relatively easy (resources for one independent outcome assessor are required). Despite this, only five studies adequately performed and reported the outcome assessment. Last, the reporting of participants lost to follow up during the studies was unclear in the majority of studies. The overall high risk of bias of studies in this field of study was also analysed by the systematic review of Kakebeeke et al. (2013). To decrease uncertainty of the findings it is important that future studies should plan and perform adequate methods to reduce the mentioned sources of risk of bias and to adhere to guidelines for reporting of randomised controlled trials.

3.4.2 Consideration of findings in relation to other focus of attention studies

Three systematic reviews comparing an EFA with an IFA were identified for similar skills (Peh et al. 2011; Kakebeeke et al. 2013; Sturmberg et al. 2013). This report is the first systematic review performing a meta-analysis. The existing reviews analysed studies qualitatively. Kakebeeke et al. (2013) included studies with healthy and participants from rehabilitation settings. They reported that in total more studies were in favour of an EFA but because of a large amount of heterogeneity a pooling was not possible. Furthermore, they recommended to apply higher standards of good clinical practice to reduce the risk of bias of future studies. Sturmberg et al. (2013) analysed the effectiveness of different FoA in people with ankle sprains. The authors reported that a significant effect on motor performance was found in favour of an EFA in two studies. However, as no pooling of the findings was possible the effectiveness in this population remains unclear. The conclusion of the review of Peh et al. (2011) that an EFA is superior for the majority of the motor skills is similar to the conclusion of this review. But Peh and co-authors suggested that the individual skill level might be a predictor variable for the effectiveness of the FoA. The findings of the meta-regression within this chapter could not support this hypothesis. At least for the included population and motor skills such an association was not visible. However, the analysis of the variable “task complexity” indicates that an EFA approach is not always superior and this should be addressed in further studies.

3.4.3 Potential biases in the review process

There are several limitations associated with this review. First, a single researcher performed the selection process. Therefore, potential eligible studies might have been missed during this process. To decrease this risk an independent researcher was approached in case of uncertainty around classifying a record.

In order to perform a meta-analysis several restrictions were set to create a relatively homogenous sample of studies. In particular, the included motor skills were restricted to be complex and not laboratory based. These criteria were set to strengthen the relevance to educational practice but a relatively large amount of studies had to be excluded because of these criteria. Inclusion of those studies might have increased the confidence in the analysis. But a meta-analysis would not have been possible due to the large amount of heterogeneity. Even in this restricted set of studies estimates of heterogeneity reached a moderate level, which was caused among others by a variety of applied outcome measures.

The sample size was very small for the analyses of the endpoints “retention” and “transfer”. Future studies might therefore change the finding of these analyses considerably.

Furthermore, the strength of the analysis is restricted because only one study was identified with a high level of complexity (Koedijker et al. 2007). The authors studied the effect on table tennis. This task is not completely predictable and high inter-trial variability occurs, which are both variables on Gentile’s complexity framework (2000). The remaining motor skills scored low on these variables. In order to strengthen the finding of the meta-regression it is important to perform more studies with complex motor skills.

A further limitation might be associated with the classification of the experience level of the participants in the included studies. Previous experience was classified within four categories and a score between 0 (no experience) and 3 (expert) was assigned. This classification was based on own reasoning and not based on literature recommendations.

3.4.4 Conclusion

Overall the results showed that an EFA was superior to an IFA for complex real-world motor skills. This was seen on post-acquisition and on retention and transfer tests. Therefore, practitioners are recommended to use an EFA for most task when an increased performance over time is desired. Furthermore, it is recommended that an EFA can be used in skill acquisition for learners with a varied previous experience. However, an EFA was not found to be superior to an IFA for all motor skills. It is probable that “skill complexity” is an important moderator variable. Motor skills with a low to moderate degree of skill complexity benefitted more from an EFA in contrast highly complex skills were better acquired with an IFA. Therefore, practitioners are encouraged to analyse skill complexity prior to the decision of the appropriate FoA. There are several recommendations for future research: i) studies are needed analysing the effectiveness of a FoA with highly complex skills, ii) future studies in this field should reduce the risk of bias by adhering to proposed standards of good clinical practice and iii) based on this systematic review it is not possible to recommend that a specific FoA can be used in physiotherapy education. It may be possible that the effectiveness analysed for complex real-world motor skills may also be valid for procedure in this educational setting. But studies within this specific setting are necessary to test this hypothesis.

4 A critical analysis of mental practice interventions in health profession education: A condensed review

4.1 Introduction - analysis mental practice interventions

This chapter is an extension to a previously published paper (Sattelmayer et al. 2016a) reporting on the effectiveness of MP (appended on page 219). In this paper, the focus was on effectiveness of MP interventions. It was recommended that MP should be considered for procedural learning in medical education. However, several aspects were not explored in depth and require further investigation. First, it was unclear how MP had been defined in HPE and different labels such as “mental imaging” or “mental practice” were used in the included studies. Second, it was unclear how MP interventions were designed regarding key variables such as timing, instructions and duration. Lastly, whether MP interventions adhered to proposed benchmarks of successful MP interventions was not appraised. These deficiencies are addressed within this chapter.

4.1.1 Mental practice

This section considers conceptual information regarding MP. First, a general definition is presented, followed by consideration of data for the effectiveness for MP and concluding with an exploration of the use of MP in HPE

MP was defined by Schmidt and Lee as “the performance of a task is mentally rehearsed in the absence of overt physical practice” (2011, p. 359). MP is a relatively broad concept and can include techniques such as thinking about a motor skill and it can also involve imagery techniques (kinaesthetic or visual or imagery). Visual imagery can be conducted with an internal or an external point of view. An external point of view means that participants are trained to view themselves from outside their bodies during the performance of a procedure. In contrast, when an internal view is used, participants image the procedure from a first person’s perspective. Kinaesthetic imaging requires the learner to concentrate on somatosensory information that is associated with the procedure (Magill 2010).

4.1.1.1 How might MP work?

The concept of “functional equivalence” can be used to explain why MP might be useful for the learning of motor skills (Jeannerod 2001). It is grounded on the idea that the brain activity is similar in physical and imagined movements.

4.1.1.2 Effectiveness of MP

Traditionally MP has been used in numerous sport disciplines to increase the skill acquisition of complex motor skills. For example, a population of pentathletes all stated that MP is routinely used to prepare for competition (Bertollo et al. 2009). In a frequently quoted paper, Landers (1983) found that MP had a considerable effect size of 0.48 on motor skill acquisition. More than 60 studies were analysed and a broad range of motor skills were included, such as juggling and dart throwing (similar effect size ranging from 0.43 to 0.78 were published by other meta-analyses. Details are presented Table 1). In addition, Feltz and Landers (1988) reported in a follow-up meta-analysis that MP can be used to accelerate the process of motor skill acquisition. More recent findings by Wohldmann et al. (2008) showed that MP can be at least as effective as physical practice for motor skill acquisition in sport. Driskell et al. (1994) reported one potential important modifying factor regarding the effectiveness of MP interventions. The authors appraised that MP was considerably more effective when the skill to be practiced involved cognitive elements. Consequently, one could argue that MP is particularly useful when students are challenged with a certain cognitive load and procedures should be selected accordingly. This raises the question “Are procedures in physiotherapeutic training cognitively demanding?” Learners have to consider several cognitive parameters to acquire and master physiotherapeutic procedures. For example, selection of the correct procedure, adjustment of the procedure to the patient and anticipation of the patient’s movements. Therefore, one could argue that physiotherapeutic procedures are sufficiently challenging to be categorised as cognitively demanding and therefore, learners could benefit from MP.

4.1.1.3 Mental practice in health professions education

Most of the published findings on the effectiveness of MP are based on studies that report movement skills in sports disciplines. It is therefore unknown whether MP can be used to improve the learning of procedural skills in the training of health professionals. Several factors differ between the two settings. For example, athletic movement skills are largely embedded in a competitive environment and are not related to the care of a patient. But the movement skills in both settings also share important parameters. First, the skills need to be adapted to different context situations. Second, procedures in both environments can be considered as challenging and complex. Last, learners have to practice either gross or fine motor skills based on the motor skill. In view of these differences and similarities, it is important to evaluate the existing findings of MP in the training of health professionals.

The previously published systematic review (Sattelmayer et al. 2016a) presented evidence that MP can be applied effectively in medical education. Eight randomised controlled trials were included in the analysis all reporting on procedures in medical education such as laparoscopic surgery or cricothyrotomy. A moderate effect size (SMD: 0.43) was found in favour of MP on post-acquisition tests. A small effect (statistically not significant) was identified in favour of MP on a retention test (SMD: 0.2).

Three points of the analysis are important for this thesis: i) procedural performance of a relatively broad range of procedures (such as basic surgical or gynaecological procedures) increased with the incorporation of MP, ii) people with different skill levels were included in the analysis and participants with both low and moderate to high prior skills seemed to benefit from MP, iii) the included studies exclusively reported on procedures in medical education (and especially surgical education). No study reported on the application of MP in physiotherapy education. Below data regarding the effectiveness of MP are presented in tabulated form (Table 4.1).

Table 4.1 Evidence table MP

Selected published systematic reviews and meta-analyses					
Review	Included studies	Population	Movement skill	Effect	Risk of bias
(Sattelmayer et al. 2016a)	15 studies (8 reported on MP)	Healthy persons in HPE settings	Procedural skills in medical education (various surgical skills, pelvic examination)	Moderate effect of MP on post-acquisition tests (SMD: 0.43, 95% CI: 0.01 to 0.85) Small effect for MP on retention test (SMD: 0.20, 95% CI: -0.56 to 0.97)	All included studies had a high risk of bias on the Cochrane Risk of Bias assessment tool.
Schuster et al. (2011)	133 studies reporting 144 interventions	Mixed population from 5 disciplines (education, music, sports, psychology and medicine)	Specific skills from the 5 disciplines (including motor and cognitive skills)	No summary effect size available. 129 interventions showed a positive effect and 12 showed a negative effect of MP. Effective MP interventions were associated with specific characteristics	Average score of 6 on a 10-point PEDRO scale for RCT's and CCT's
Influential studies (i.e. most cited studies in the field)					
Review	Google scholar citations*	Population	Movement skills	Effect	Design
Landers (1983) and Feltz et al. (1988)	1505	Mixed population (60 studies were included in meta-analysis)	Various skills, most were related to sport skills (such as handball or bowling), some skills were related to cognitive skills (such as maze learning)	Moderate effect size of 0.48 (SD: 0.67) for MP on skill acquisition. Effect size for training of cognitive tasks was 1.44 compared to 0.43 for motor tasks	Meta-analysis
(Driskell et al. 1994)	1118	Mixed population: sports, music, psychology (35 studies reporting on 3214 subjects)	Skills from various disciplines were included. Tasks were analysed with regard to their cognitive elements.	Moderate effect size of 0.53 in favour of MP on skill acquisition. When mental and physical practice were used in combination an effect size of 0.78 was appraised. Effect was stronger in tasks with more cognitive elements.	Meta-analysis

* based on a search in March 2018; MP: mental practice; HPE: health professions education

4.1.2 Aim

The aim of the rest of this chapter is to critically analyse the structure and application of MP interventions in HPE. Three specific objects are associated with this aim: First, to analyse how the concept "mental practice" is defined and used in this setting. Second, to analyse the structure of different MP interventions with the TIDIeR scale (Hoffmann et al. 2014). Finally, to evaluate whether the MP interventions were designed in such a way that they adhered to proposed benchmarks for MP interventions.

4.2 Methods - analysis mental practice interventions

4.2.1 Literature search

Studies for this condensed review were included from a previously published systematic review (Sattelmayer et al. 2016a) in the area. The search strategy was updated to identify recent studies in Pubmed via Medline. That is the same combination of keywords was used as presented in (Sattelmayer et al. 2016a) but restricted to MP. The search string is presented in Table 4.2. Identified records were imported in a literature management system (Endnote X7) and a single reviewer screened the records regarding the selection criteria.

Table 4.2 Search strategy

Population	Intervention	Outcome
medical education OR education, medical [Mesh] OR physiotherapy education OR physical therapy education OR health professionseducation OR healthcare education	mental imagery OR mental practice OR mentalrehearsal	performance OR learning OR proficien* OR mastery OR competenc* OR skills OR skill OR procedur* OR assessment OR comparative OR compare OR comparison OR measure* OR evaluat* OR educational measurement

* indicates a truncation search

4.2.1.1 Selection criteria

The following selection criteria were used to triage the identified records of the search update: i) studies had to report about students in HPE, ii) at least one study intervention had to be MP, iii) MP was compared against nMP iv) only randomised controlled trials were included.

4.2.2 Evaluation of concept "mental practice"

All included studies were checked for a definition or conceptual information of the term "mental practice". Furthermore, if available the reference for this definition was extracted. Information was extracted whether the interventions were classified as "mental practice", "mental imaging" or used other not pre-specified labels but could be identified as using core MP elements.

4.2.3 Evaluation of the structure and reporting of the intervention

The TIDieR scale (Hoffmann et al. 2014) was used to identify information relevant for the evaluation of the MP intervention. The TIDieR scale includes key features of interventions such as duration, dose and further details, which are necessary to evaluate complex interventions. The following items were extracted: "what" (the materials used), "who provided", "how" (the mode of delivery), "where" (location of the intervention), "when and how much" (e.g. amount of practice sessions), "tailoring" (e.g. was the intervention personalised), "modifications" (were there modifications during the course of the study) and "how well" (intervention adherence).

4.2.4 Evaluation of best practice variables

The MP interventions were appraised regarding several criteria. Schuster and colleagues (Schuster et al. 2011) have proposed best practice elements for MP interventions (based on a systematic review of 133 studies investigating the use of MP in five different settings). The best practice elements were associated with successful MP interventions. All included studies were appraised whether they fulfilled the following elements: supervision of the MP session (i.e. supervised sessions seemed to be more effective than unsupervised sessions), timing of the MP (MP after physical practice was appraised as more promising), perspective of the MP (an internal, first person, perspective seemed to be more promising than an external perspective), modalities of the cues (kinaesthetic cues seemed to work better than other cues) and focus of the task (a focus on motor tasks was associated with better results). Last, it was evaluated how the MP script was developed (i.e. studies should report how they developed the MP script. Previously validated scripts or a clearly stated development strategy were classified as fulfilling this criterion. This criterion was added to guidelines presented by Schuster et al. (2011) because a review of the included studies revealed considerable heterogeneity between studies regarding this variable. The items were graded with the following categories: A: fulfilling variable (2 points), B: unclear or partly not fulfilling (1 point) and C: not fulfilling variable (0 points).

4.3 Results - analysis mental practice interventions

First, the results of the literature search are presented, then the included definitions and conceptual information of the MP are reported, then the analysis of included studies with the TIDIeR items is presented and last, the integration of best practice variables is analysed.

4.3.1 Results of the literature search

The literature search was designed as an update on a systematic review published in 2016. Within this paper seven studies were included for the comparison of MP against nMP. The search on Pubmed yielded n = 75 new records. The seven studies included in the 2016 review were also added to the pool of eligible records. After screening of the titles and abstracts n = 60 records were excluded. The remaining n = 22 records were read as full-texts. Of those n = 12 were excluded with the following reasons: i) one study was excluded because of an inadequate intervention (Alam et al. 2016), ii) three studies were excluded because of inadequate comparisons

(Chadha et al. 2016; Lim et al. 2016; Lorello et al. 2016) and iii) eight studies were excluded because of the study design (Geoffrion et al. 2012; Cocks et al. 2014; Paige et al. 2015; Ignacio et al. 2016; Mick et al. 2016; Weller 2016; Anton et al. 2017; Davison et al. 2017). Finally, ten studies were included in this review (Sanders et al. 2004; Bathalon et al. 2005; Sanders et al. 2008; Komesu et al. 2009; Arora et al. 2011; Jungmann et al. 2011; Geoffrion et al. 2012; Louridas et al. 2015; Conlin et al. 2016; Shah et al. 2017). The study flow is presented in Figure 4.1.

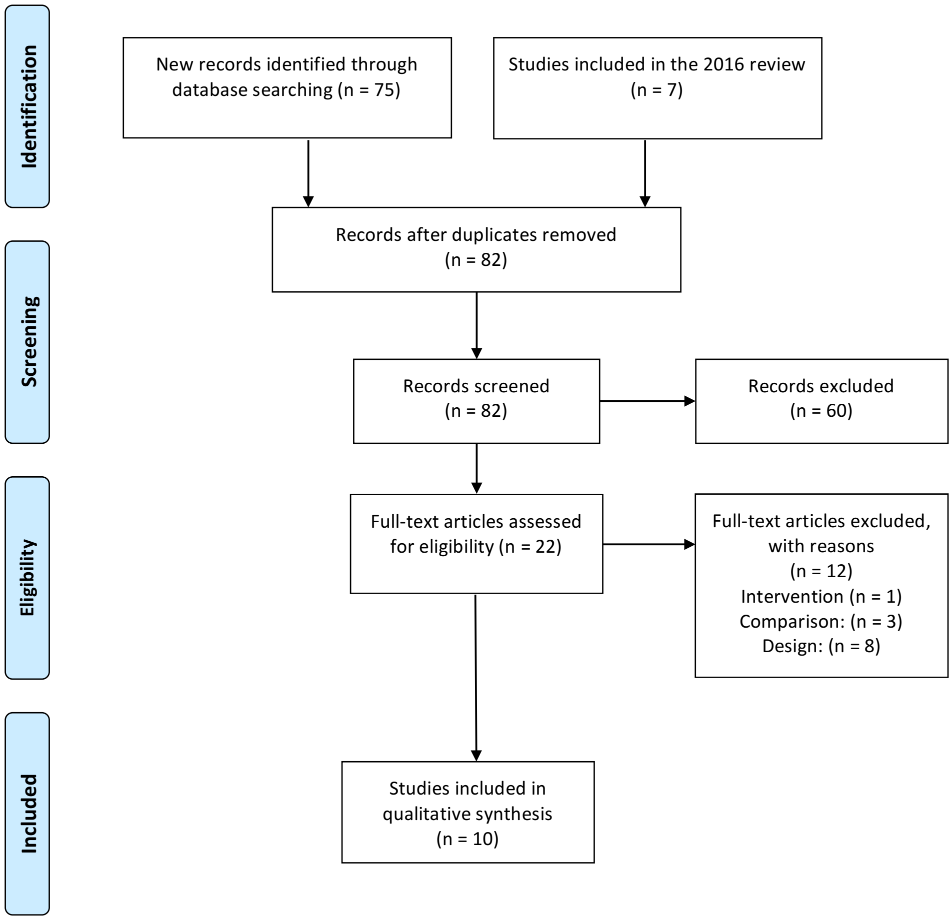


Figure 4.1 Flow of studies during the review process

4.3.2 Evaluation of the concept "mental practice"

There was no consensus whether the intervention should be labelled "mental practice" or "mental imaging". Three of the included studies (Arora et al. 2011;

Louridas et al. 2015; Conlin et al. 2016) classified their intervention as “mental practice” whereas the remaining seven studies used the term “mental imaging”. Despite the use of different labels the general concept was defined similarly across studies, with all studies reporting that “mental rehearsal” of a task is a key element of the concept. Seven studies further clarified that the rehearsal is performed in absence of physical movements. Three studies referenced a study by Driskell et al. (1994) to define the concept of “mental practice / image” in their intervention. Then two studies cited works by Richardson. However, Richardson used both labels. In 1967, he used “mental practice” (Richardson 1967) and in 1969 the term “mental imaging” was selected (Richardson 1969).

The studies by Diskrell and colleagues and Richardson are all frequently referenced papers in the field of MP (indicated by their citations on Google Scholar with 1118, 975 and 431 citations in March 2018). Two studies referenced to a single study and three studies did not provide a reference for the concept of their intervention. Furthermore, it was noted that some studies labelled their intervention as “mental imaging” and referenced to a source which used the label “mental practice” or vice versa. For example, Komesu et al. (2009) used the label “mental imaging” and referenced to Richardson (1967), who used the label “mental practice”. Therefore, based on the same conceptual information used in the included studies to define the concepts “mental practice” or “mental imaging” and the use of similar references one might conclude that both terms are used as synonyms in this setting or at least as very close related concepts with no clear differences between them. An overview of the used labels and definition of concepts is presented in Table 4.3.

Table 4.3 Overview of the labels and concepts used in the included studies

Study	Label	Definition	Reference
(Sanders et al. 2004)	Mental imaging	"In preparing to operate, surgeons often report performing the operation in their ''mind's eye,'' using mental imagery to rehearse the procedure, especially when the operation is unusual or difficult"	EDWARDS, J. C., SADOSKI, M. & BURDENSKI JR, T. K. 2004. Physicians' reported use of mental images and language in clinical reasoning. *Imagination, Cognition and Personality,* 24, 41-49.
(Bathalon et al. 2005)	Mental imaging	"Mental imagery can be defined as the symbolic repetition of a physical action without the muscular counterpart"	RICHARDSON, A. 1969. *Mental imagery,* New York, Springer.
(Sanders et al. 2008)	Mental imaging	"The technique of visualisation, or mental imagery, is popular in many fields, where it is used for mental rehearsal, relaxation or goal-setting purposes, as well as in psychotherapy."	Not reported
(Komesu et al. 2009)	Mental imaging	"Mental imagery is the symbolic rehearsal of a physical activity in the absence of any gross muscular movements"	RICHARDSON, A. 1967. Mental practice: a review and discussion part I. *Research Quarterly. American Association for Health, Physical Education and Recreation,* 38, 95-107.
(Arora et al. 2011)	Mental practice	"Mental practice, that is, the cognitive rehearsal of a task in the absence of overt physical movement"	DRISKELL, J. E., COPPER, C. & MORAN, A. 1994. Does mental practice enhance performance? *Journal of applied psychology,* 79, 481.
(Jungmann et al. 2011)	Mental imaging	"Mental imagery – mental training, referred to as "visualizing" or "quasi-perceptual experience", … . The systematic and repeated imaging of a movement without actually performing it has been widely researched in sport psychology"	Not reported
(Geoffrion et al. 2012)	Mental imaging	"Mental imagery is the cognitive rehearsal of a task in the absence of overt physical movement"	ARORA, S., AGGARWAL, R., SEVDALIS, N., MORAN, A., SIRIMANNA, P., KNEEBONE, R. & DARZI, A. 2010. Development and validation of mental practice as a training strategy for laparoscopic surgery. *Surgical endoscopy,* 24, 179.
(Louridas et al. 2015)	Mental practice	"Mental practice, defined as the cognitive rehearsal of a task without physical movement, is used to improve performance in many fields"	Not reported
(Conlin et al. 2016)	Mental practice	"Mental practice is the cognitive rehearsal of a task in the absence of overt physical movement"	DRISKELL, J. E., COPPER, C. & MORAN, A. 1994. Does mental practice enhance performance? *Journal of applied psychology,* 79, 481.
(Shah et al. 2017)	Mental imaging	"Mental imagery, the ability to see and feel an activity without physically carrying it out."	DRISKELL, J. E., COPPER, C. & MORAN, A. 1994. Does mental practice enhance performance? *Journal of applied psychology,* 79, 481.

4.3.3 Evaluation of the structure and reporting of the interventions

Key intervention features are presented below according to the TIDieR scale. All included studies were appraised for these items and the detailed findings are presented in Table 4.4.

4.3.3.1 What was used?

The structure and the required material of the MP interventions differed to some degree between studies. While all studies prepared a MP script for the participants other elements differed between the studies. Five studies (Sanders et al. 2004; Sanders et al. 2008; Arora et al. 2011; Conlin et al. 2016; Shah et al. 2017) integrated relaxation exercises into the MP interventions. Three studies presented videos recordings of experts performing the procedure (Arora et al. 2011; Jungmann et al. 2011; Louridas et al. 2015). Conlin et al. (2016) explicitly reported the use of detailed illustrations to support the MP training the remaining studies did not provide this information (i.e. whether illustrations were integrated into the MP scripts). A different approach (consisting of two steps) was reported by Bathalon et al. (2005) they asked the participants to first practice the surgical procedure with paper and pen. The next step was MP without physical movement and without the use of the paper and pen.

4.3.3.2 Who provided?

Heterogeneity existed regarding the personnel providing the intervention. The MP interventions were either provided by psychologists or by faculty members of the relevant discipline. Combinations were also possible. This was seen in two studies (Sanders et al. 2004; Sanders et al. 2008) using relaxation exercises prior to the MP interventions (i.e. the psychologist provided the relaxation exercises and faculty members supervised the MP).

4.3.3.3 Mode of delivery

All included studies instructed the exercises face-to-face. Some authors used an individual setting (i.e. instructor and participant together) while others instructed the exercises to a group of participants.

4.3.3.4 Location

Only one study reported this item. Sanders et al. (2008) explicitly stated that a quiet and comfortable room was used for the intervention. One might assume that the remaining authors instructed the intervention in a discipline related environment but the specifics remained unclear.

4.3.3.5 When and how much?

The timing of the first MP session ranged from between 5 to 30 minutes (e.g. Arora et al. 2011) . MP was performed i) once or twice under supervision (Geoffrion et al. 2012), ii) individually with a certain prescribed amount of practice, for example 3 minutes a day over 4 days (Jungmann et al. 2011), and Louridas et al. (2015) scheduled three sessions with telephone support.

4.3.3.6 Tailoring

All studies used standard MP interventions and therefore, none of the scripts were personalised.

4.3.3.7 Modifications

No changes in interventions were reported in the included studies.

4.3.3.8 How well?

Adherence to the MP intervention was controlled by the instructor (when a face to face instruction was scheduled). When studies used individual training sessions without supervision the adherence to the intervention was in some instances unclear (Bathalon et al. 2005; Geoffrion et al. 2012; Conlin et al. 2016; Shah et al. 2017). Jungmann et al. (2011) tried to control adherence to the individual exercises by asking students to report the amount of practice they have performed.

Table 4.4 Evaluation of the structure of and reporting of the interventions in included studies

Study	What?	Who?	Mode of delivery	Location	When & how much?	Tail-oring	Modi-fication	How well?
(Sanders et al. 2004)	Relaxation, guided imagery instructions	Psychologist, physician	Face to face (individual)	Unclear	30 min instruction and relaxation session	No	No	Supervised MP sessions
(Bathalon et al. 2005)	Simulator, MP script, paper and pen (to train procedure)	Unclear	Face to face instruction (group)	Unclear	5 min instructions, individual practice as often as possible	No	No	Unclear
(Sanders et al. 2008)	Relaxation, guided imagery instructions	Psychologist, physician	Face to face (individual)	Quiet and comfortable room	2x 30 min instruction and relaxation sessions	No	No	Supervised MP sessions
(Komesu et al. 2009)	Instructional video for educational faculty, MP script	Faculty members	Face to face (individual)	Unclear	20 min imagery session	No	No	Supervised MP sessions
(Arora et al. 2011)	MP script, relaxation, video recording, MP with talk-out loud	Unclear	Face to face (individual)	Unclear	30 minutes MP protocol	No	No	Supervised MP sessions
(Jungmann et al. 2011)	Video and checklist of procedure, MP instructions	Unclear	Group instruction, students performed MP self-dependent	Unclear	Practice over 4 days not less than 3min per session	No	No	Students reported amount of MP
(Geoffrion et al. 2012)	Instructional video for educational faculty, MP script	Trained faculty member	Face to face instruction (individual) and individual practice	Unclear	Two supervised MP sessions and individual practice	No	No	Unclear
(Louridas et al. 2015)	Didactic lecture, instructional videos, MP script	Experienced psychologist	Face to face instruction (individual)	Unclear	Three telephone calls with repetition and retention test	No	No	Supervision during telephone call
(Conlin et al. 2016)	Textbook, MP script, illustrations, relaxation exercises	PI, read script to the participants	Face to face instruction (group)	Unclear	Participants were asked to prepare for the retention test after 48 h	No	No	Unclear
(Shah et al. 2017)	Simulator, mental imagery script, relaxation exercises	Mentor	Face to face instruction (group)	Unclear	Instruction session, amount of MP not reported	No	No	Unclear

MP: mental practice; PI: primary investigator

4.3.4 Evaluation of best practice variables

Below the included studies are evaluated regarding selected best practice items. All ratings are presented in Table 4.5.

4.3.4.1 Supervision of the intervention

All included studies instructed the MP intervention under supervision and therefore fulfilled this best practice element. However, four studies (Bathalon et al. 2005; Jungmann et al. 2011; Conlin et al. 2016; Shah et al. 2017) scheduled group sessions with supervision, which was classified as less favourable compared to individual supervised sessions (Schuster et al. 2011).

4.3.4.2 Timing of the mental practice intervention

Two studies performed the MP prior to the physical practice (Komesu et al. 2009; Louridas et al. 2015) and were therefore appraised as not fulfilling this criterion. One study was rated as unclear on this item as no information was retrieved regarding the timing of the MP intervention (Geoffrion et al. 2012).

4.3.4.3 Focus of the task

All included studies were appraised as satisfying this criterion because the MP interventions focussed on procedures with motor tasks.

4.3.4.4 Modalities of the cues used during the mental practice

Three studies did not specify the modality of the used cues (Sanders et al. 2004; Sanders et al. 2008; Komesu et al. 2009) and were rated as unclear on this item. Jungmann et al. (2011) designed their MP intervention with visual and cognitive cues but did not integrate kinaesthetic cues. Therefore, the study was classified as not satisfying this criterion. All remaining studies reported the use of kinaesthetic cues in their interventions.

4.3.4.5 Perspective of the mental practice

This item was poorly reported in the included studies. Only one study reported that an internal perspective was used during the MP (Arora et al. 2011). The remaining studies did not explicitly report the instructed perspective and were rated as unclear on this item.

4.3.4.6 Script development

Five studies were classified as fulfilling this criterion. The highest standards were scripts designed with the help of experts, which were validated prior to the use in the studies (Arora et al. 2011; Conlin et al. 2016). Then, Louridas et al. (2015) designed their script with a panel of experts and two studies designed the MP scripts with the help of a literature study (Bathalon et al. 2005; Geoffrion et al. 2012). The remaining studies were rated as unclear on this item due to lack of available information.

Table 4.5 Classification of included studies regarding best practice criteria for mental practice

Study	Supervision	Sup. grade	Timing	Timing grade	Focus	Focus grade	Modality	Modal. grade	Perspective	Persp. grade	Script	Script grade	Total points
Sanders (2004)	Individual familiarisation	★ A	Mental practice after physical practice	★ A	Motor task	★ A	Unlcear	✔ B	Unlcear	✔ B	Unlcear	✔ B	9
Bathalon (2005)	Within group instruction	✔ B	Mental practice after physical practice	★ A	Motor task	★ A	Focus on kinaesthetic cues	★ A	Unlcear	✔ B	Based on literature study	✔ B	9
Sanders (2008)	Individual familiarisation	★ A	Mental practice after physical practice	★ A	Motor task	★ A	Unlcear	✔ B	Unlcear	✔ B	Unlcear	✔ B	9
Komesu (2009)	Individual familiarisation	★ A	Mental practice prior to physical practice	✖ C	Motor task	★ A	Unlcear	✔ B	Unlcear	✔ B	Unlcear	✔ B	7
Arora (2011)	Individual familiarisation	★ A	Mental practice after physical practice	★ A	Motor task	★ A	Visual, cognitive and kinaesthetic cues	★ A	Internal	★ A	Validated script	★ A	12
Jungmann (2011)	Within group instruction	✔ B	Mental practice after physical practice	★ A	Motor task	★ A	Visual and cognitive cues	✖ C	Unlcear	✔ B	Unlcear	✔ B	7
Geoffrion (2012)	Individual familiarisation	★ A	Unclear	✔ B	Motor task	★ A	Visual, cognitive and kinaesthetic cues	★ A	Unlcear	✔ B	Based on textbooks	✔ B	9
Louridas (2015)	Individual familiarisation	★ A	Mental practice prior to physical practice	✖ C	Motor task	★ A	Visual and kinaethetic cues	★ A	Unlcear	✔ B	Expert interviews	★ A	9
Conlin (2016)	Within group instruction	✔ B	Mental practice after physical practice	★ A	Motor task	★ A	Visual, cognitive and kinaesthetic cues	★ A	Unlcear	✔ B	Validated script	★ A	10
Shah (2017)	Within group instruction	✔ B	Mental practice after physical practice	★ A	Motor task	★ A	Visual, cognitive and kinaesthetic cues	★ A	Unlcear	✔ B	Unlcear	✔ B	9

Key. A: fulfilling variable (2 points), B: unclear or partly not fulfilling (1 point) and C: not fulfilling variable (0 points)

4.4 Discussion - analysis mental practice interventions

4.4.1 Concept "mental practice"

The main finding regarding the conceptualisation and definition was that the included studies defined their interventions relatively homogenously. The authors reported that the intervention was the "mental rehearsal" of a procedure. Some authors further stated that physical movements are absent during the mental rehearsal. Despite this homogeneity there was no consensus whether the intervention should be labelled as "mental imaging" or "mental practice". One attempt to distinguish between the terms "mental practice" and "mental imaging" was made by Schuster et al. (2011). They reported that "mental practice" is a more general term and includes various MP interventions. In contrast, "mental imaging" is used to address the mental imagination of a body part. The included studies in this review used different approaches for their MP intervention. For example, some included relaxation exercises prior to the mental rehearsal. Therefore, an informed decision was made to use the more general term "mental practice" in this report and in the following chapters of the thesis.

4.4.2 Evaluation of the structure and reporting of the interventions

The findings of the analysis of the structure and reporting of the MP interventions showed that considerable heterogeneity existed in regard to several variables: First, all studies used some sort of MP script, which can be consequently regarded as a minimal requirement for MP interventions in HPE. However, different material was used to support the participants during the MP. Some studies showed videos of experts performing the intervention and others used illustrations. There are no established benchmarks regrading this variable and future studies are needed to investigate the appropriate supporting material.

Second, several authors integrated relaxation exercises into the intervention. The purpose of these exercises was to help the participants to attain a calm and relaxed state before the MP of the procedure (Sanders et al. 2008). Then, in some cases

psychologists were used to instruct the MP intervention. This creates considerable barriers to the use of MP outside of a controlled study because of inadequate resources. A more pragmatic approach would be to develop guidelines for a MP intervention with the help of an experienced psychologists. But these guidelines should be designed in such a way that faculty members could supervise the MP.
Third, the mode of delivery was face to face in all included studies. However, some authors instructed each individual while others instructed groups of participants. It is plausible that individual instructions might be more effective. For example, individual questions might be answered more specifically. However, the routine use of individual instructions may not be feasible due to inadequate resources in many educational settings. Therefore, studies investigating the effectiveness of group instructions probably better reflect current educational practice possibilities.
Fourth, the timing and dose for the intervention varied considerably between studies. With different durations reported of instructional sessions. Then, in some cases the participants were asked to practice on their own, while others practiced under supervision. A recommendation for future studies would be to investigate the optimal dose and timing of a MP interventions. This is justified by the high heterogeneity of this variable in the included studies.
Last, if participants are asked to use MP on their own, appropriate measures should be implemented to control for adherence. The used measures varied between studies and only one study (Jungmann et al. 2011) asked the participants to report the amount of performed MP.

4.4.3 Evaluation of best practice variables

One study fulfilled all best practice criteria for MP interventions (Arora et al. 2011). The remaining studies were classified as unclear on at least one criterion. Two studies (Komesu et al. 2009; Louridas et al. 2015) instructed the MP prior to physical practice, which was classified as unfavourable. Regarding the used cues, it was appraised that older studies (i.e. prior to 2010) did not precisely report the modalities of their cues. And only one study (Jungmann et al. 2011) did not specifically instructed kinaesthetic cues and was therefore classified as not meeting this criterion. A recommendation for further studies is to clearly report the perspective of the MP training. All but one studies were classified as unclear on this criterion. The best practice benchmark for this criterion was a first-person perspective. The reports from most of the included studies indicated that a first-person perspective was used, but this was not specified. Therefore, this problem might be solved by better reporting.

Last, the highest standard of script development was only met in two studies (Arora et al. 2011; Conlin et al. 2016). Both developed their scripts in two phases. First, expert interviews were performed to design the MP scripts and to identify relevant cues. The experts were asked to perform a cognitive walkthrough of the performance and verbalise what they see, feel, hear and think during the procedure. In a second phase the MP scripts were validated in a pilot study. This thorough method can be regarded as benchmark for the process of script development and future studies should strive to follow this approach.

4.4.4 Limitations

Several limitations are associated with this report. First, the update of the literature search was performed in a single database (Medline). Therefore, potential studies may have been missed. However, this report is a condensed review about the structure and application of MP interventions in HPE and not a systematic review about the effectiveness of MP. One of the aims was to inform clinicians how to perform a MP intervention and which elements should be considered prior to the use of MP in educational settings. It is not likely that an additional study would have changed the findings of the analysis. For pragmatic reasons potential eligible records were screened by one person in case of doubt an independent researcher was contacted but not all records were screened by two persons.

In order to evaluate the included studies several best practice criteria proposed by Schuster et al. (2011) were used. These criteria were identified in a systematic review, but the size of each individual item is not known (i.e. each item is either classified as favourable or unfavourable). In a future study the weight of each criterion (or predictor variable) should be analysed (e.g. with the help of meta-regression). Furthermore, an additional item “script development” was added to the best practice criteria. The reason for this was, that studies used different methods to design the MP scripts. The integration of expert thoughts and prior validation was appraised as a systematic and sound method. However, this method can be further explored in future studies. Last, the first two items of the TIDIeR scale were not presented. The first item “name” of the intervention was already presented in a previous section and the second item “rationale” was not presented, because all MP interventions aimed to increase procedural skills. The information is not missing in this manuscript but was presented differently.

4.4.5 Conclusion

MP is relatively homogenously defined in HPE. In contrast, the terms “mental practice” and “mental imaging” are both used to label MP interventions in this setting. The structure and design of the MP interventions showed considerable heterogeneity regarding several key variables. The integration of best practice variables for MP revealed that a considerable amount of studies was appraised as unclear on several variables. This should be addressed with clear reporting in future studies. Especially, the reporting of how the MP script were developed must be reported in more detail, because the MP scripts are one essential part of MP interventions. When MP interventions are used in an educational setting educators are encouraged to design the interventions to incorporate several best practice variables. However, in most educational settings it might not be possible to address all proposed variables because of restricted resources.

5 Development and validation of a mental practice script for a transfer procedure for people with hemiparesis after stroke

5.1 Introduction - Development and validation of a mental practice script

In chapter 4 several possible ways to develop a MP script were identified in studies using MP interventions in HPE. It was recommended that MP scripts should be designed in sound way. One study (Arora et al. 2011) was identified, which fulfilled all proposed best practice criteria for MP (Schuster et al. 2011). Furthermore, (Arora et al. 2011) presented a higher effect size in favour of MP compared to no MP than other studies, which did not report their method of script development or used a non-systematic way (Sattelmayer et al. 2016a). Therefore, a MP script was designed using a similar approach as presented by (Arora et al. 2010).

For the RCT presented in chapter 6 the teaching of two different procedures were investigated. A transfer to the ground with a stroke patient and a set of vestibular rehabilitation procedures. Especially, for the transfer procedure the approach of (Arora et al. 2010) seemed to be appropriate because of the following reasons: First, there exists no established standard how to teach the procedure and a degree of variability exists within the procedure (i.e. there is a need to adapt the procedure to specific patients). Therefore, this procedure was selected to design a MP script with the help of experts and validate the preliminary script.

The script for the other procedure “vestibular rehabilitation” was not developed using the same approach because of the following reason: These procedures are extensively presented in existing literature and guidelines exists how to perform the procedure (Herdman and Clendaniel 2014) and it was possible to extract sufficient information from these sources to design a MP script. Furthermore, this procedure is highly standardised and no modifications should be performed.

5.1.1 Aim

The aim of this study was to develop and validate a MP script for a transfer procedure in physiotherapy education.

5.2 Methods - Development and validation of a mental practice script

The development of the MP script for the procedure "transfer to the ground with a stroke patient" was performed in two parts. The first part relates to the preliminary development of the script and the second part is the validation of the script with the help of a convenience sample.

5.2.1 Part 1 - Development of the mental practice script

The MP script was developed with the help of protocol analysis and expert thought (Ericsson 2006). Three physiotherapists from neurological rehabilitation with considerable experience were recruited for the script development. All physiotherapists were interviewed and interviews were audio-recorded. During the interviews, the physiotherapists were asked to perform the procedures mentally and perform a cognitive walk-through of the procedure. I.e. the physiotherapists were asked to recall a transfer procedure as they experience the procedure during a real patient encounter. During the mental performance physiotherapists were asked to think aloud about how they were performing the procedure and to report relevant cues (e.g. visual or cognitive cues) during each phase of the procedure. The interviewer prompted for cues if no cues were spontaneously provided by the physiotherapists. Afterwards the audio recordings were analysed for relevant cues. For each procedural part kinaesthetic, visual and cognitive or other cues were identified and documented on a transcript. Procedure parts used by the physiotherapists were compared against a classification of possible procedure parts performed by the primary investigator a priori. Both the list of identified cues and the identified procedure parts were send back and the physiotherapists were asked to check the script for completeness. In case of no reported procedure parts the physiotherapists were asked to consider why they did not report that part and whether they thought it should be used in the MP script.

Finally, the three transcripts were merged to produce a single MP script. To reduce the content of the MP script to a feasible length, cues were reduced with a steps-wise approach (e.g. cues were combined or deleted).

5.2.2 Part 2 - Script validation

The design of the validation study was a repeated pre- and post-test measurement study (i.e. a comparison of two related conditions within a single group was performed).

5.2.2.1 Participants

Eleven physiotherapy undergraduate students (3rd year) were recruited from the University of applied Sciences and Arts Western Switzerland Valais by convenience sampling.

5.2.2.2 Procedure

Participants were instructed how to mentally practice the procedure “transfer to the ground with a stroke patient” using the script developed in part 1 of this study. The instruction sessions had a duration of 20 minutes. Afterwards the participants mentally practiced the procedure 20 minutes under supervision. The practice sessions consisted of three parts. First the procedure was imagined as complete procedure consisting of all relevant sub-parts. Then each part was mentally practiced individually. Finally, the complete procedure was practiced once again. Furthermore, participants were instructed to use an internal first-person perspective for the imagery.

5.2.2.3 Measurement

Performance of the participants was measured with two endpoints. A pre-test was scheduled immediately before the MP session and a post-test was performed immediately after the session. Participants were not aware of the scheduled post-test. During both endpoints two assessments were administered. The first assessment was a Mental Imagery Questionnaire (MIQ) (Cumming et al. 2007). The MIQ in this study was slightly modified to allow an assessment of the transfer procedure used in this study. The MIQ consisted of seven items and all items rate aspects related to the capacity to image the transfer procedure (e.g. MIQ 4 measures: “How easily can you “see” yourself performing a “transfer to the ground”?) The second assessment in this study was the time participants needed to perform the procedure mentally. This measurement approach was proposed by (Jeannerod 1995) to evaluate the capacity to image a specific movement.

Two hypotheses were proposed a priori regarding the validation of the MP script.

> i) There will be no significant difference in the capacity to image oneself after instruction using a MP script. With the research hypothesis being: there will be a significant difference in the capacity to image oneself after instruction using a MP script.
>
> ii) There will be no significant difference in the the time needed to perform the procedure mentally oneself after instruction using a MP script. With the research hypothesis being: there will be a significant difference in the capacity to image oneself after instruction using a MP script.

The assumption for these hypotheses were that the MP script would enrich the mental imagery process by providing relevant cues. Consequently, participants would be able to see themselves in more detail (i.e. higher MIQ scores) and would need more time to perform the procedure mentally.

5.2.2.4 Data analysis

All data were imported into R version 3.3.3. Data analysis was performed with the “stats” package (R Core Team 2014) and the “ggplot2” package (Wickham 2016) was used for data visualisation. To test whether data should be analysed with parametric or non-parametric statistics an approach presented by Field (2012) was used. First skewness and kurtosis was analysed, then density and qq-plots were checked visually for non-normality and lastly a Shapiro Wilk test (1965) was performed. Due to signs of non-normality an informed decision was made to use the Wilcoxon signed-rank test (Wilcoxon 1946) for the analysis of change in both outcome measures (i.e. MIQ scores and time needed to perform the procedure mentally). To quantify the magnitude of the findings effect sizes were calculated for both analyses based on Rosenthal (1991). Effect sizes were interpreted as presented by Cohen (1992).

5.3 Results - Development and validation of a mental practice script

5.3.1 Part 1 - Development of the mental practice script

Three experienced physiotherapists were invited to participate in the script development study. All three had considerable experience in working with stroke patients and reported that they perform the "transfer to the ground" procedure on a regular basis during their work. The years working in neurological rehabilitation ranged between 7 and 11 years. Additional details of the participants are presented in Table 5.1.

Table 5.1 Demographic data of the script development study participants

Demographic data		
Gender		2 ♀, 1 ♂
Handedness		3 right
Age (years)	mean (SD),	36.33 (8.67)
	median (IQR)	38 (3.5)
Years working in neurological rehabilitation	mean (SD)	8.67 (2.08)
	median (IQR)	8 (2)

All physiotherapists were interviewed to gather a verbal explanation of how they performed the procedure. The length of the interview ranged from 2462 (physiotherapist 1) to 1493 (physiotherapist 3) words. Interviews were coded regarding relevant procedure parts and cues.

Cues were categorised into "cognitive and other cues" (i.e. cues related to thinking and decision-making processes that occur during the procedure), visual cues (i.e.

cues related to seeing oneself or the patient during the procedure) and “kinaesthetic cues” (i.e. cues related to moving and feeling oneself or the patient during the procedure).

The analysis of the interviews identified 111 cues (physiotherapist 1), 76 cues (physiotherapist 2) and 51 cues (physiotherapist 3). Most cues were identified in the categories “Cognitive and other cues” (physiotherapist 1 and 2) and “Kinaesthetic cues” (physiotherapist 3). Overall the physiotherapists rarely used visual cues. Only 8 visual cues were identified in all three interviews (Figure 5.1). All identified cues were re-checked with each expert individually to verify relevance of the cues.

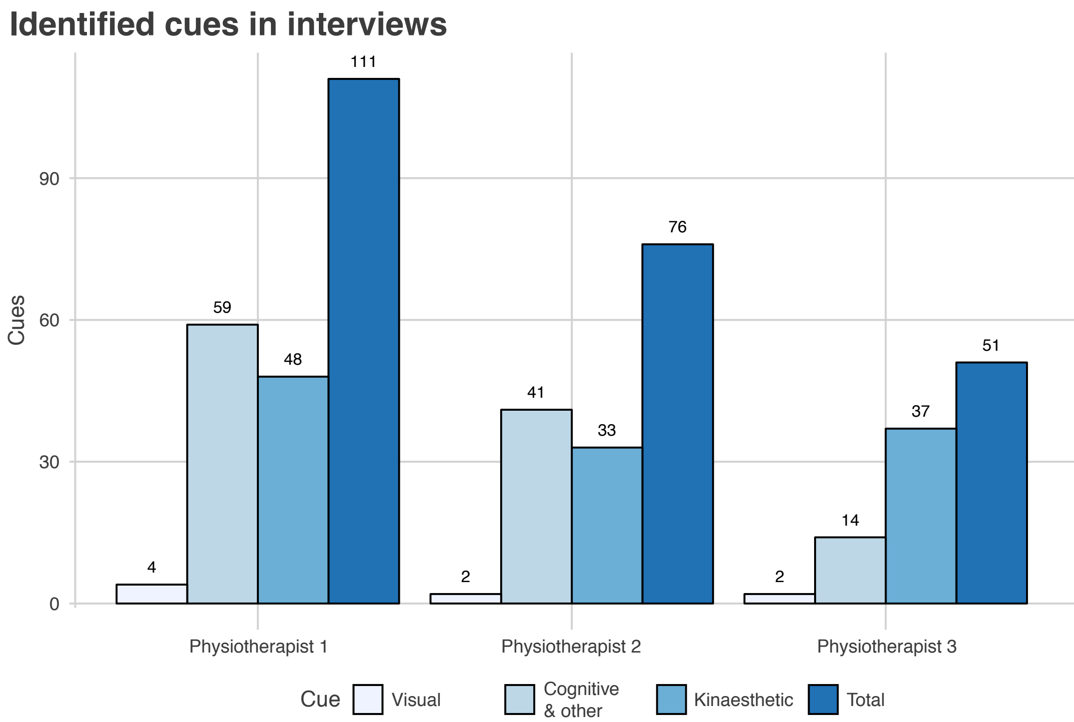


Figure 5.1 Identified cues in interviews with three experienced physiotherapists

In comparison to the first classification of movement parts performed by the primary investigator, which was used as a reference, the experts used less elements to perform the procedure.

Sixteen procedure parts were originally identified for the procedure. However, the experts performed their procedures differently. For example, the fourth procedure part of the originally classification was "the physiotherapist corrects the foot position …". None of the three physiotherapists reported this element in their interviews nor did they classify this item as essential on request. This was also analysed for procedure part 5 "the physiotherapist controls a sideways movement …". Therefore, relevant parts of the procedure were extracted from the interviews, compared to the original classification and after verification with the experts a MP script consisting of 12 procedure parts was designed (Table 5.2).

Table 5.2 Classification of procedure parts

ID	First classification of procedure parts	ID	Amended classification of procedure parts
1	The patient is sitting on a bench and is instructed to turn his body to the non-paretic side.	Pre	Preparation and general information is provided.
2	The patient is asked to place the paretic knee on the ground. The physiotherapist supports the paretic hip.	1	The patient is sitting on a bench and is instructed to turn his body to the stronger side.
3	The patient places the non-paretic knee on the ground and is situated in kneel-standing.	2	The patient is asked to place the weaker knee on the ground.
4	The physiotherapist corrects the foot position and relieves pressure on the patient's toes.	3	The patient places the stronger knee on the ground and is situated in knee-standing.
5	The physiotherapist controls a sideways movement of the patient away from the treatment table	4	The patient is instructed to place both arms on the ground.
6	The patient is instructed to place both arms on the ground.	5	The patient is instructed to sit down on one side.
7	The patient is instructed to sit down on one side.	6	The patient is instructed to lie on the mat.
8	The patient is instructed to lie on the mat.	7-11	The patient is asked to get up and to sit on a bench
9 - 16	The patient is getting up into a standing position. Steps 1 - 8 are reversed.		

After the definition of relevant procedure parts the identified cues of the physiotherapists were merged into a single MP script. This script consisted initially of 79 relevant cues. To reduce the number of cues to an amount, which can be instructed and used in a single MP session the number of relevant cues was stepwise reduced. From the original 79 cues a MP script consisting of 42 cues was designed (Figure 5.2). Within this process, the category “cognitive and other cues” was further elaborated into two different categories (i.e. “cognitive cues” and “collaborative cues”). The latter was defined as cues related to procedure elements that should be performed in collaboration between physiotherapist and patients.

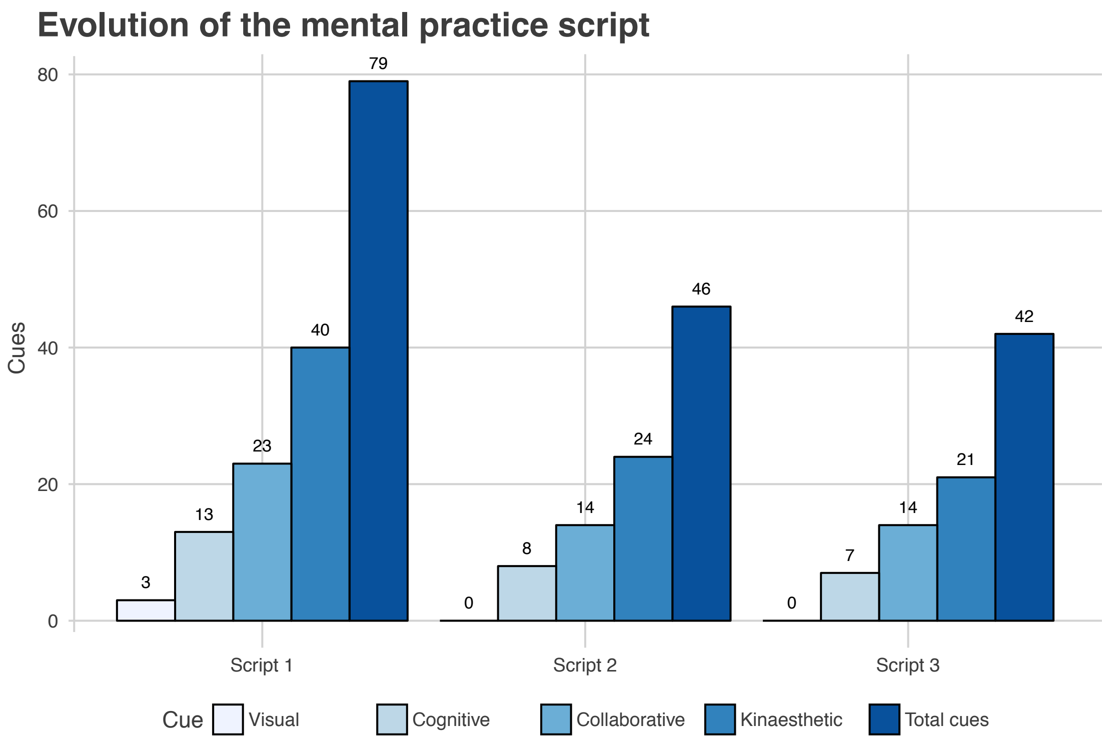


Figure 5.2 Evolution of the MP script

To ensure that the script did not contain too much information, the maximal number of cues for a single part was set to five cues, which was the case for part 5 (i.e. four kinaesthetic and one cognitive cue). Five procedural parts contained four cues (i.e. part 2, 3, 7, 8 and 9). The script for the remaining procedural parts was built with three or less cues (Figure 5.3). During the procedure parts 5, 7 and 10 cognitive cues are used to support the physiotherapists in their decision-making processes. At each of these procedure parts therapists can decide to modify the procedure based on the performance of the patient. For example, during the procedure part 5 physiotherapists must decide whether the patient is going down over the weaker or stronger side. To facilitate the decision-making process possible reasons are presented such as shoulder pain, shoulder instability or uncertainty about the patient's abilities. All procedure parts and corresponding cues are presented in Appendix iii.

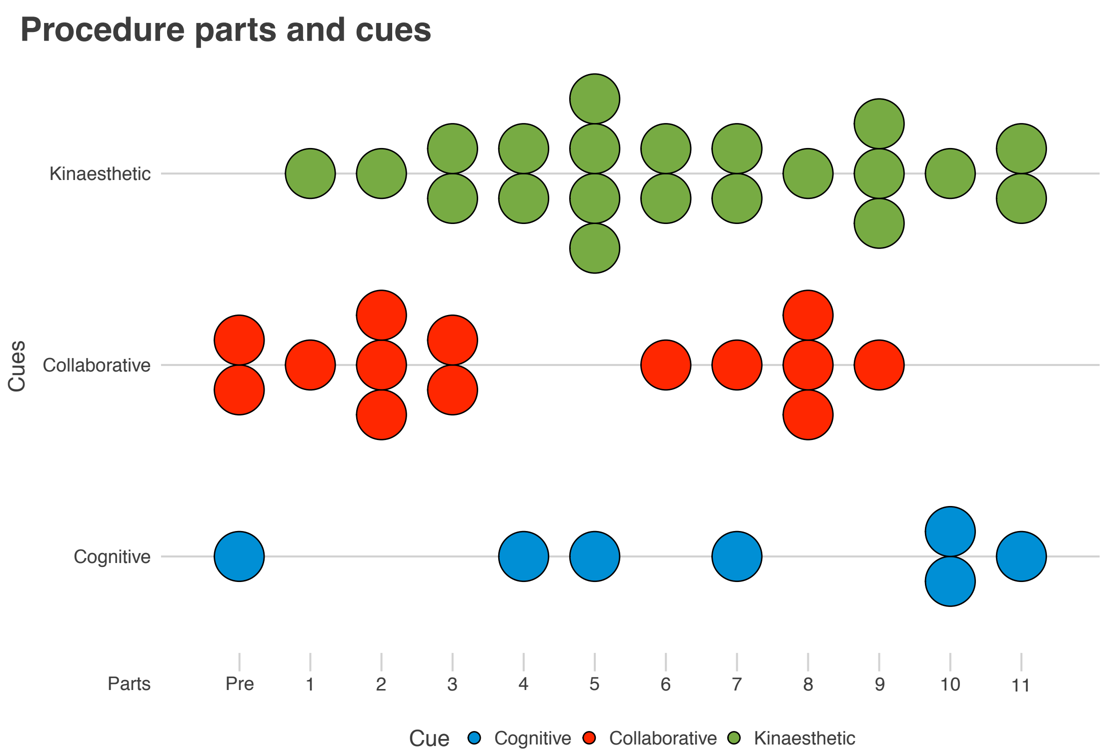


Figure 5.3 Parts of the transfer procedure and related cues

5.3.2 Part 2 - Validation study

A convenience sample of eleven third-year undergraduate physiotherapy students were recruited to validate the MP script for the transfer to the ground procedure. Baseline descriptive statistics of the participants are presented in Table 5.3. Participants were on average 23.64 (SD: 1.63) years old. All participants had previous experience with the procedure. The number of performed transfer procedures ranged between 3 and 20. Furthermore, the students had experienced formal teaching of the procedure during their education. This was evidenced by a capacity to perform the procedure mentally and by an average score on the MIQ of 30.55 (SD: 6.52).

Table 5.3 Demographic and educational data of the validation study participants

Demographic data		
Gender		11 ♀
Handedness		9 right, 2 left
Age (years)	mean (SD), median (IQR)	23.64 (1.63) 24 (1)
Educational data		
Experience with procedure; i.e. number of procedures performed	mean (SD) median (IQR)	8.00 (4.65) 7 (5)
MIQ score at baseline (0 - 49 points)	mean (SD) median (IQR)	30.55 (6.52) 32 (7.5)
Time needed to perform the procedure mentally in seconds at baseline	mean (SD) median (IQR)	80.82 (28.28) 76 (37)

Data of the MIQ at the pre- and post-test was checked regarding its normality with an approach presented by Field (2012). The following information was analysed i) skewness and kurtosis did not tend against zero (values ranged between - 0.37 and - 0.79), ii) density and QQ-plots presented some indications of non-normality (Figure 5.4) and iii) the Shapiro-Wilk test was non-significant (p: 0.85 and p: 0.30) for both endpoints. Due to the findings of the first two points and the fact that only eleven participants were recruited for the validation study an informed decision was made to use non-parametric statistics for the analyses.

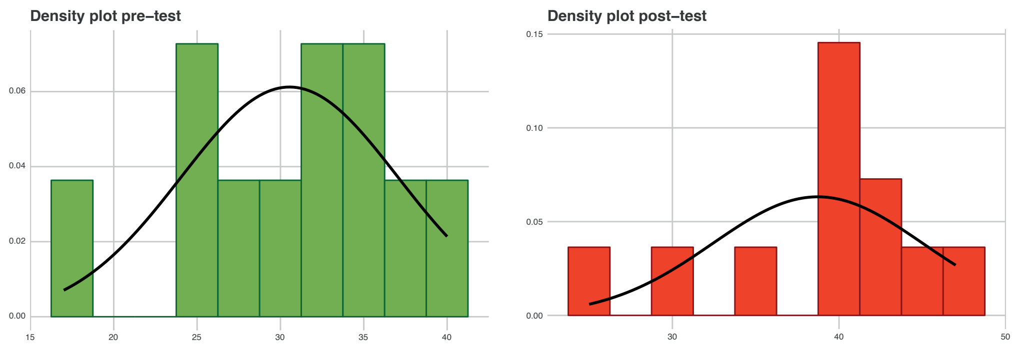


Figure 5.4. Density plots for the MIQ at the pre- and post-test endpoint

5.3.2.1 Hypothesis 1

The first hypothesis to validate the script was that participants would increase their capacity to mentally image the transfer procedure after application and use of the script.

Participants had a median score of 32 (IQR: 7.5) points on the MIQ at the pre-test. The score increased to 40 (IQR: 4.5) points at the post-test. The difference between the two tests was statistically significant (p: 0.003) with a large effect size (r: -0.89).

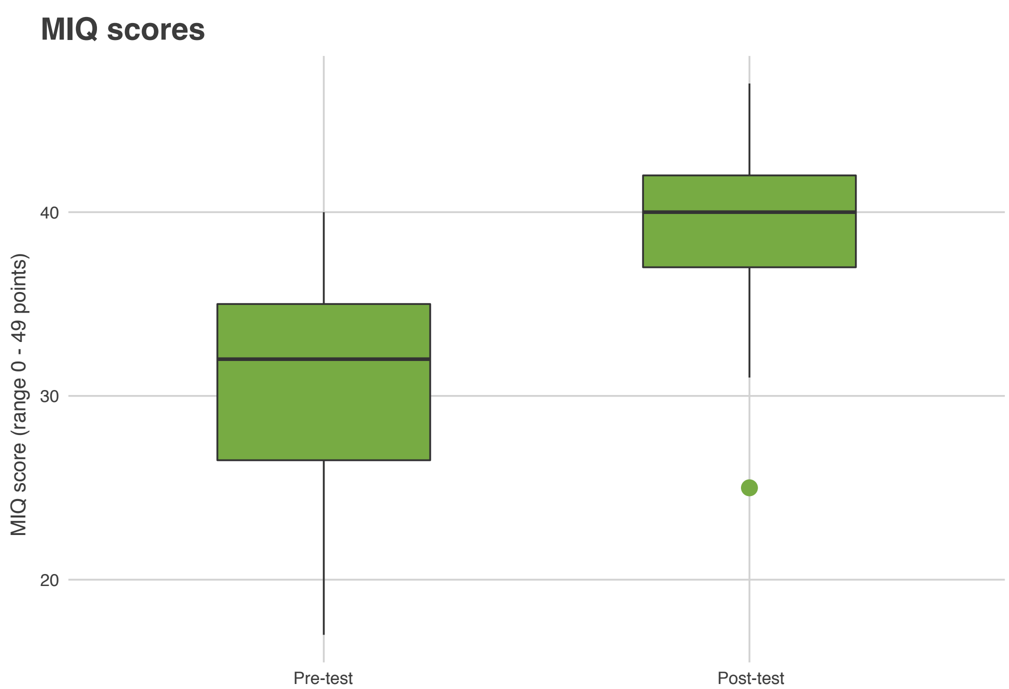


Figure 5.5 MIQ total scores at the pre- and post-test

One outlier was identified for the post-test (Figure 5.5). Participant ID 4 had a score of 25 points on the MIQ at the post-test. However, regarding the pre-test, the participant increased 8 points on the MIQ.

Data for each item of the MIQ is presented in Table 5.4. All MIQ item scores increased from the pre-test to the post-test. The increase from pre-test to post-test was statistical significant for all MIQ items with exception of item MIQ 3. Effect sizes ranged between r: -0.87 (MIQ 1) to r: -0.54 (MIQ 3). MIQ 1 “How confident do you feel to carry out a transfer” showed the largest change score of 1.36 points (SD: 0.81). MIQ 3 “How well do you think you can perform a transfer compared to others at your stage” showed the smallest increase in change with a mean of 0.73 points (SD: 1.19).

Table 5.4 MIQ scores for the pre-test, post-test and change scores

MIQ item		Pre-test	Post-test	Change	Effect size & Significance
MIQ 1	mean (SD)	4.36 (0.92)	5.73 (0.90)	1.36 (0.81)	r: -0.87
(0 - 7 points)	median (IQR)	5 (1)	6 (1)	1 (0.5)	(p: 0.004)*
MIQ 2	mean (SD)	4.45 (1.44)	5.55 (0.93)	1.09 (1.04)	r: -0.72
(0 - 7 points)	median (IQR)	5 (1)	5 (0.5)	1 (2)	(p: 0.016)*
MIQ 3	mean (SD)	4.91 (1.22)	5.64 (0.92)	0.73 (1.19)	r: -0.54
(0 - 7 points)	median (IQR)	5 (1.5)	6 (0)	0 (1.5)	(p: 0.071)
MIQ 4	mean (SD)	4.18 (0.87)	5.55 (1.37)	1.36 (1.12)	r = -0.77
(0 - 7 points)	median (IQR)	4 (0)	6 (2.5)	1 (2)	(p: 0.010)*
MIQ 5	mean (SD)	4.45 (1.51)	5.82 (1.08)	1.36 (1.43)	r: -0.73
(0 - 7 points)	median (IQR)	4 (2)	6 (1)	2 (1.5)	(p: 0.015)*
MIQ 6	mean (SD)	3.82 (1.08)	5.00 (1.00)	1.18 (0.75)	r: -0.82
(0 - 7 points)	median (IQR)	4 (1)	5 (1)	1 (1)	(p: 0.006)*
MIQ 7	mean (SD)	4.36 (1.36)	5.45 (1.13)	1.09 (1.04)	r: -0.83
(0 - 7 points)	median (IQR)	4 (2)	6 (1)	1 (0.5)	(p: 0.008)*
MIQ total	mean (SD)	30.55 (6.52)	38.73 (6.31)	8.18 (3.95)	r: -0.89
(0 - 49 points)	median (IQR)	32 (7.5)	40 (4.5)	8 (4)	(p: 0.003)*

NB. Wilcoxon signed-rank test was used to test for statistical significance; * indicates statistical significant change values

5.3.2.2 Hypothesis 2

The second hypothesis was that participants would increase the time to perform the procedure mentally after application and use of the script. At the pre-test, a median score of 76 (IQR: 26) seconds was recorded. The time increased to a median score of 165 (IQR: 50.05) seconds. The difference was statistically significant (p: 0.007) with a large effect size (r: -0.81).

Performance of one participant ID 1 deviated from the performance of the remaining sample. The participant required considerable more time to perform the procedure mentally compared to the other participants with 136 seconds at the pre-test and 330 seconds at the post-test. (Figure 5.6).

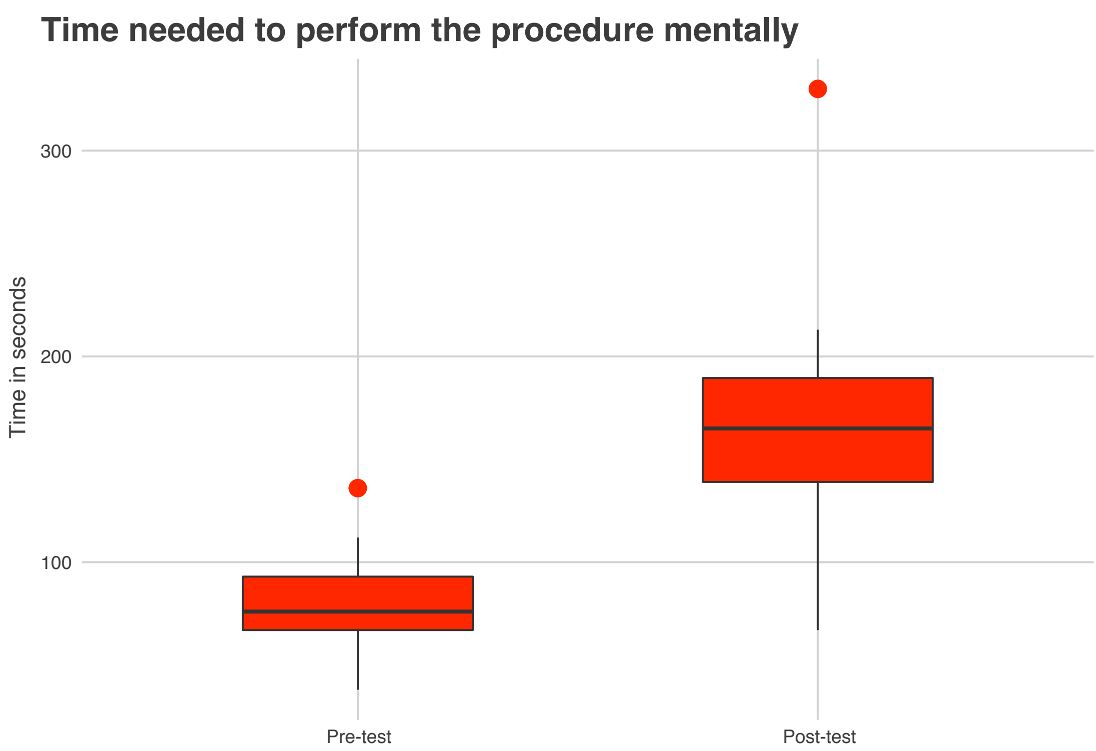


Figure 5.6 Time needed to perform the procedure mentally at the pre- and post-test

5.4 Discussion - Development and validation of a mental practice script

The main findings of this study was that it was possible to develop a MP script for a transfer procedure in physiotherapy education using an approach presented by Arora et al. (2010). Furthermore, two hypotheses proposed a priori to validate the script were confirmed. The ability to mentally perform the procedure (measured with the MIQ showed a large increase) and the time to perform the procedure mentally also increased considerably after instruction and use of the MP script. The analysis of the interviews revealed that cues from different categories were reported from the physiotherapists (i.e. kinaesthetic, cognitive, visual and collaborative). Most cues were categorised as kinaesthetic cues. This indicates that learners have to acquire several motor skills to sufficiently perform the transfer procedure. For example, to support the weight shift of a patient and providing stability to hip and trunk requires the learner to perform multiple actions simultaneously. Especially, part 5 of the procedure with 4 kinaesthetic cues and 1 cognitive cues may present challenges during the acquisition of the procedure. Furthermore, the large amount of procedure parts and cues indicate that this procedure can be classified as highly complex. The presence of various different cues shows that the procedure corresponds to essential points of the conceptualisation of procedures as presented in chapter 2. That is, it involves knowledge about manual skills (i.e. kinaesthetic cues), decision-making skills (i.e. cognitive cues), communication with the patient (i.e. collaborative cues) and patient-focussed interaction (i.e. collaborative cues). Therefore, it seems reasonable to select this procedure for further investigation of the acquisition of procedural skills in physiotherapy education.

5.4.1 Limitations

The interview with the three experienced physiotherapists identified a large number of relevant cues. For pragmatic reasons the number of cues was considerably decreased. This reduction was performed carefully but it might be possible that potential relevant cues were eliminated from the script. Furthermore, the script does not contain visual cues. Only very few visual cues were reported by the experts (i.e. less than 4 % of the total number of cues) and during the evolution of the script these cues were deleted from the script. The elimination of cues was performed carefully and in case of uncertainty external advice was searched. Furthermore, the final script was presented to the experts and these were asked to check the script for completeness. The remaining 42 cues in the final MP script represent a large number of cues for a single procedure and may represent a considerable challenge for participants to memorise during the training. However, a further reduction of cues might have increased the chance to eliminate critical information from the MP script. A further limitation of this study was the recruitment of 3rd year undergraduate students in the form of a convenience sample. This establishes a narrow data base and reduces the external validity of this study (Kam et al. 2007). However, this was undertaken for pragmatic reasons and also that the main target population for the main study were not reduced.

5.4.2 Agreement with other studies

Several best practice variables were used to appraise existing MP scripts in chapter 4 of this thesis based on the systematic review of Schuster et al. (2011). The script for the transfer procedure was designed to fulfil these criteria. First, the instruction and practice was supervised. For pragmatic reasons group supervision was chosen. An internal, first person perspective was instructed for the MP. The script included kinaesthetic cues as well as collaborative and cognitive cues. The focus of the procedure is on motor skills (i.e. most of the cues are related to kinaesthetic cues). Last, the script was developed in a two-step process, which included expert interviews to identify cues and the validation of the script in a later phase. Only one criterion of the best variables was not fulfilled (i.e. the timing). As this study did not involve physical practice it was not possible to schedule the MP after the physical practice. However, the script fulfilled the majority of proposed best practice variables.

The findings of this study are similar to the study of (Arora et al. 2010). The increase in MP abilities was large and statistically significant on the MIQ after instruction of the MP script. A direct comparison of the study findings was not possible because of the following reasons: i) a slightly modified version of the MIQ was used and ii) the samples differed regarding the previous experience with the procedure. Arora and co-authors recruited two samples. One consisted of novices and one of experts. Within this study the participants had some prior experience with the procedure but all were still based in undergraduate education.

Another study using a similar approach to validate a MP script was published by (Conlin et al. 2016). The authors report that participants found the script “helpful” but data regarding MIQ scores were not reported. Both studies (Arora et al. 2010; Conlin et al. 2016) identified a large number of visual cues for their surgical procedures. This is in contrast to the transfer procedure where these were only rarely reported. However, both studies were performed in surgical education and certain differences are inevitable. It is possible that the fine motor skills in surgery require a much greater ability to visually control the procedure. In contrast, the transfer procedure (with corresponding gross motor skills) may require more kinaesthetic control.

5.4.3 Conclusion

A MP script for a transfer procedure in physiotherapy education was developed and validated. After use of the MP script, the abilities of the participants to mentally image the procedure increased considerably as did the time needed to perform the procedure mentally, both findings indicating that participants were able to imagine more specific details of the procedure. The script consists of 42 cues. The majority of the cues are related to kinaesthetic cues (i.e. moving and feeling oneself or the patient during the procedure), collaborative cues, and cognitive cues (i.e. thinking and decision-making). The script can be used in physiotherapy education to support the acquisition of a transfer procedure but may need further refinement. Future research should set out to analyse the effectiveness of this MP script in a randomised controlled study. Research in physiotherapy education might consider using this approach to develop and validate MP scripts for other relevant procedures in this field.

6 LEArN trial

6.1 Introduction - LEArN trial

The LEArN (Learning of procEdures in physiotherApy educatioN) trial is presented within this chapter and is the major component of work in this thesis.

As discussed in previous chapters the acquisition of procedures is a key element in physiotherapy education. Therefore, evidence based educational interventions are required, which can potentially support i) physiotherapy students during their skill acquisition and ii) educators by providing methodological tools to increase the effectiveness of their teaching. Different educational methods exist to support the acquisition of procedures in this setting, which require among others considerable resources (such as technology-based interventions). In chapter 2 and 3 motor learning principles were explored (i.e. FoA and MP), which are used in practice to increase skill acquisition of motor skills in sport or in medical education. However, no study has explored the effectiveness and feasibility of these principles in physiotherapy education. To fill this knowledge gap the LEArN trial was developed.

The LEArN trial consisted of two study arms, within each arm the acquisition of a specific task procedure was investigated. Task procedure 1 was a transfer procedure and task procedure 2 was a procedure from vestibular rehabilitation. Within the method section the overall trial methods are reported in full (such as trial recruitment, endpoints, outcome measures and statistical methods) in order to avoid unnecessary repetition. In the result and discussion sections, the findings of the two task procedures are reported and discussed separately.

6.1.1 Study aim and objectives

This pilot study evaluated the application of two motor learning principles (MP and FoA) on the learning of procedural skills in physiotherapy education. Several parameters required investigation within this study.

The primary objective was to estimate the effectiveness of the motor learning principles on performance of procedural skills. Performance of the participants was measured with several outcome measures. All outcome measures provided different performance related information (e.g. expert based ratings of the performance or time needed to perform the procedure, further details are presented in section 6.2.6.2). The following research hypotheses were set:

Comparison MP versus nMP:

- H_1: There will be a significant difference in performance measures between a procedural skills training using MP and a training using nMP on post-acquisition and retention tests.

Comparison EFA versus IFA:

- H_1: There will be a significant difference in performance measures between a procedural skills training using an EFA and a training using an IFA on post-acquisition and retention tests.

The secondary objective was to analyse the feasibility of this study with several feasibility criteria. All feasibility criteria are further presented in section 6.2.6.5.

6.2 Methods - LEArN trial

6.2.1 Design

This research was a pilot study with a randomised controlled trial design. It can be classified as "Development of concept trial" (Dobkin 2009) and the effectiveness and feasibility of two motor learning principles in physiotherapy education were evaluated on two task procedures. The same enrolment, allocation and follow up processes were used for both task procedures. For each task procedure, a four-arm randomised controlled trial design was used, with the groups A (MP), B (nMP), C (EFA) and D (IFA) (Figure 6.1 on page 106).

6.2.2 Participants

A convenience sample of 79 year 2 and year 3 BSc physiotherapy students from the University of Applied Sciences Western Switzerland Valais (UAS Valais) were invited to participate in the LEArN trial (i.e. for task procedure 1 and 2). A research assistant, not involved in teaching the procedures, approached the potential participants.

The reason for this selected group were, that the curriculum of the university anchors the selected procedures within the second (vestibular rehabilitation procedure) and the third year (transfer procedure) at the UAS Valais.
A research assistant not involved with teaching at the UAS Valais provided information about the study to potential participants followed by received written information (Appendix iv). The potential participants had four days to consider the study and if they decided to participate, they completed written informed consent.

6.2.2.1 Inclusion criteria

- 2nd and 3rd year undergraduate physiotherapy students at the UAS Valais

6.2.2.2 Exclusion criteria

- Prior formal training with regard to the procedures

6.2.3 Ethics

The study received approval from the Commission cantonale d'éthique de la recherche sur l'être humain (CER-VD) Switzerland (2016-12-08, Appendix v) and the ethical committee of Queen Margaret University (2017-02-17, Appendix vi). As the participants in this study were students at the UAS Valais where the primary investigator was a lecturer, some potential risks and benefits were associated (e.g. power differentials).

6.2.4 Randomisation

Participants in both the transfer (task procedure 1) and the vestibular rehabilitation (task procedure 2) arm of the study were randomly assigned, via a computer generated random number table, to one of four educational groups (i.e. A, B, C or D). Previous performance during university-based procedural skills examinations was regarded as potential confounding variable and therefore stratification was used to ensure an equal distribution of this variable. Four strata, based on previous performance were generated (i.e. high, above average, below average and low performer). The randomisation was performed in R using the blockrand package (Snow 2013) by an independent person not employed at the UAS Valais.

6.2.4.1 Allocation concealment

Details of the participants were provided to the person performing the randomisation by email (i.e. a central allocation was performed). The allocation sequence was concealed to the personnel performing the intervention until participants were officially registered to a study arm.

6.2.5 Intervention

6.2.5.1 Task procedures used

Two different complex procedures were trained during this study. The procedure for the third-year student's procedural skills training was a transfer to the ground for a person with a stroke (task procedure 1). The procedure for the second-year students was a set of procedures from vestibular rehabilitation (task procedure 2). Both procedures are complex for novice practitioners and consist of multiple movement parts that require a set of specific movement skills. The procedures were identified as being challenging to learn based on the primary investigator's educational experience teaching these procedures.

The reason for conducting this study with two different procedures was that both procedures vary to some degree (e.g. with regard to their movement parts, complexity or previous experience of the students). Therefore, it was anticipated that this would provide more insight into the application and analysis of motor learning principles.

6.2.5.2 Training of procedures

The procedural skills training was undertaken by one educator and lasted 1.5 - 2 hours. First a general introduction to the procedure was provided, which covered theory and a general guideline. Then the specific procedure (dependent on group allocation) was demonstrated. Group size for the procedural skills training was 12 persons or less.

- Group A received a procedural skills training which consisted of mental and physical practice (group MP).
- Group B received a procedural skills training which consisted of physical practice and no mental practice (group nMP)
- Group C received a procedural skills training which consisted of physical practice structured with an EFA.
- Group D received a procedural skills training which consisted of physical practice structured with an IFA.

The MP script for the transfer procedure was developed and validated a priori (chapter 5). The MP script concerning the vestibular rehabilitation was designed based on cues identified in Herdman and Clendaniel (2014). The FoA scripts were developed using specific rules (Table 6.1). These were based on recommendations published by Wulf et al. (2002).

Table 6.1 Rules used to develop the FoA scripts

External focus of attention	Internal focus of attention
Focus on the patient	Focus on the therapist's body segments (e.g. arm)
Focus on the result of a movement	Focus on therapist's body movements
References to specific body parts of the therapist were avoided	References to specific body parts of the therapist were encouraged

All educational scripts are appended on page 219 or can be downloaded from: https://martinsatt.rbind.io/project/learn-trial

6.2.6 Outcomes

The outcome measurement was carried out by rating video recordings of students performing the trained procedure.

6.2.6.1 Endpoints

Two different endpoints, to assess learning, were used. A post-acquisition test on a peer student was conducted immediately after the procedural skills training (T1).

The same procedure was performed two weeks after the acquisition phase to ascertain retention (T2). At T2 the procedure was performed on a trained standardised "patient" (i.e. healthy volunteers) simulating a person suffering from stroke or a vestibular disorder. Instructions for the standardised "patients" were developed by the PI. Procedures at T1 and T2 were video recorded and performance was evaluated based on pre-determined criteria.

6.2.6.2 Outcome measures

Performance of the procedure and therefore an indication of the effectiveness of the educational interventions was measured with the outcome measures given below at endpoints T1 and T2.

6.2.6.2.1 Procedural skills

The primary outcome for effectiveness were procedural skills. The construct procedural skills was measured with the Assessment for Procedural Skills in Physiotherapy Education 29 (APSPT 29), which is a measurement instrument designed as part of the doctoral programme by the PI to evaluate the performance of procedures in physiotherapy education. The APSPT 29 is a generic assessment for procedural skills (i.e. it can be used for various procedures in physiotherapy) and contains six subcategories (preparation, knowledge and decision-making, communication, safety, procedure execution and comfort) with a total of 29 items (Appendix vii). The APSPT 29 has been investigated in a previous pilot study and demonstrated adequate functioning with regard to internal consistency and structural validity (Sattelmayer et al. 2016b). The APSPT 29 total score can range between 0 to 116 points. Higher points indicate a better performance.

6.2.6.2.2 APSPT Sub-dimension procedure execution

The items of the APSPT's sub-dimension "procedure execution" were also analysed separately. The sub-dimension consists of seven items (i.e. six specific items such as "appropriate hand and finger placement" and one overall assessment of the procedure execution). This sub-dimension was analysed separately because it seemed plausible that these items might be more sensitive to motor learning interventions than the remaining items of the APSPT 29. For example, items of the communication sub-dimension are probably less sensitive to interventions focussing on motor behaviour. The score of this measurement could range between 0 and 28 points. Higher scores indicated a better performance.

6.2.6.2.3 Procedure specific aspects

A procedure specific checklist (PSC) was used to evaluate specific aspects of the procedures. The checklist contained critical points of the procedures as identified in chapter 5 (Transfer) and in and Herdman and Clendaniel (2014) for the vestibular rehabilitation procedure. More specifically, procedure specific elements were rated on a trichotomous scale (Appendices viii and ix). The PSC total score could range between 0 and 24 points (transfer procedure) and between 0 and 26 points for the vestibular rehabilitation procedure. Higher scores indicated a better performance.

6.2.6.2.4 Response time

Response time is a core measure of procedural skills in HPE with important educational implications. Response time has been analysed to be a sensitive measure of change, which can detect training induced changes in novices and experts in motor learning research (Starkes et al. 1998). Furthermore, many studies evaluating motor learning principles in HPE used response time as an outcome (Sattelmayer et al. 2016b). Response time was reported in seconds.

6.2.6.2.5 Self-reported confidence

Three items from a six item questionnaire designed to evaluate self-reported confidence of procedural skills in medical education (Sanders et al. 2004) were used. The omitted items measured confidence in surgical procedures and therefore were not relevant to physiotherapy education. The total score could range between 0 and 12 points. Higher scores indicated a higher self-reported confidence (Appendix x).

6.2.6.2.6 Mental practice ability

The ability of participants to image the procedures was measured with a mental chronometry approach (Decety et al. 1989; Jeannerod 1995). This measurement was developed based on the finding that the response time of performing an imaged movement had almost exactly the same duration compared to a physical execution of the same movement (Decety et al. 1989). The mental chronometry approach has been used in several studies evaluating MP in rehabilitation settings (e.g. in persons with multiple sclerosis (Allali et al. 2012) or in persons with schizophrenia (Lallart et al. 2012)). The difference between physical and mental response time was reported in seconds.

6.2.6.3 Blinding of participants and educator

Students were not informed which specific motor learning principles were compared. Obviously, the educator performing the procedural skills training was aware of the specific motor learning principle to use in instruction.

6.2.6.4 Blinding of outcome assessors

An independent physiotherapist with experience in the procedures (not employed at the UAS Valais), evaluated the performances on the video recordings. The physiotherapist was unaware of the group allocation of the students. The other outcomes were evaluated by the PI.

6.2.6.5 Feasibility criteria

The feasibility of the motor learning principles was evaluated with several parameters. Feasibility criteria for this pilot study were identified in Thabane et al. (2010) and Van Teijlingen and Hundley (2002).

6.2.6.5.1 Recruitment rate

The recruitment rate was calculated by subtracting the recruited participants from the participants meeting the eligibility criteria. A recruitment rate lower than 50% would raise doubts about the feasibility of a larger study.

6.2.6.5.2 Failure rate

If there was a failure to perform the procedure, this was investigated for all participants and for each specific group. Previous experience led to the expectation that the majority of the participants should have been able to perform the procedure adequately after procedural skills training. Feasibility of the approach to acquiring the procedural skill might be considered questionable if more than 40% of the participants could not perform the procedure effectively. The independent video rater classified each performance as adequate or not adequate based on a general impression of the performance (i.e. did major mistakes of serious safety issues occur).

6.2.6.5.3 Feasibility of the procedural skills training session

Following the training, the educator completed a short questionnaire regarding the feasibility of the training sessions (e.g. difficulties and challenges using the principles). In addition, participants completed a short questionnaire to evaluate the training sessions in order to identify issues using the motor learning principles.

6.2.6.5.4 Feasibility of the outcome assessment

The length of time needed and challenges to administer the tests were measured. The outcome assessors provided this information after each rating. Furthermore, it was appraised whether the equipment worked reliably (i.e. sufficient quality of the video recordings).

6.2.6.5.5 Sample size

The effect size of the primary outcome for effectiveness (APSPT 29) was used to cautiously estimate the sample size for a larger follow up study as proposed by Dupont and Plummer (1990) with the G*Power 3 application (Faul et al. 2007).

6.2.7 Data analysis

All statistical analyses were performed with the programme R (version 3.4.3). All data were first entered on a hard copy paper form that was subsequently entered electronically by a research assistant. Personal details were stored in a separate filing cabinet (i.e. the master list with names was stored separately). Names in the database were replaced with an identification code.

6.2.7.1 Descriptive statistics

Baseline characteristics of the participants (gender, age, primary language and previous evaluation of procedural skills were described overall and per intervention group.

Summary tables using median (IQR) and mean (SD) statistics were created for all outcome variables. It was chosen to present these summary statistics i) to illustrate the data distribution and ii) to allow integration of the study data into future meta-analyses, which might require mean and SD values.

6.2.7.2 Analyses of effectiveness

Separate analyses were performed for the groups (1A, 1B, 1C and 1D) training the transfer procedure (task procedure 1) and the groups (2A, 2B, 2C and 2D) training the vestibular rehabilitation procedure (task procedure 2). For both the transfer and vestibular rehabilitation procedure analyses comparing performance of the MP versus nMP groups (1A versus 1B and 2A versus 2B), and comparing the performance of the EFA against IFA groups (1C versus 1D and 2C versus 2D) were undertaken.
Data were checked regarding normality in order to determine the appropriate analysis (Field 2013). Distributions were checked graphically, followed by evaluation of skewness and kurtosis, followed by statistical testing for normal distribution (Shapiro and Wilk 1965). Based on the three evaluations an informed decision was made regarding data distribution.
The evaluations indicated that the data were non-normally distributed. Therefore, non-parametric tests, the Wilkinson's rank-sum test (Wilcoxon 1945), were used to compare the performance between groups and an effect size was presented for all analyses (Rosenthal et al. 2000). Effect sizes were interpreted as presented by Cohen (1992): an effect size (r) of 0.1 represented a small effect, a moderate effect was associated with 0.3 and a large effect was related to an effect size of 0.5 or more.
The secondary outcomes and the different endpoints were analysed the same way. However, due to the large number of outcome measures a correction for multiple tests was applied using the Benjamini and Hochberg (1995) procedure as this was considered as being more powerful than the classical Bonferoni correction for multiple testing (McDonald 2009).
All analyses were performed as intention-to-treat analysis (Newell 1992). This implies that all participants allocated to a specific group were analysed together, regardless whether or not they received or completed the procedural skills training.

6.2.7.3 Missing Data

If participants decided to withdraw from the study they were asked if they also wanted to discontinue with the follow up measures. Missing data were obtained by performing multiple imputations (MI) using the MICE package in R (Buuren and Groothuis-Oudshoorn 2011). The following steps were performed to impute missing values: i) it was inspected whether the missing at random assumption seemed plausible, ii) variables were imputed for each group separately to ensure non-violation of the intention-to-treat principle (Sullivan et al. 2016), iii) all variables in the data set were included in the imputation process, iv) a univariate imputation technique was selected for each variable with missing values (i.e. numeric variables were imputed using predictive mean matching, which is more reliably working on non-normal distributed data sets than standard linear regression imputation (Rezvan et al. 2015), v) the number of performed imputations was set to six to avoid a large Monte Carlo error (Rezvan et al. 2015), vi) all imputed values were checked for plausibility (i.e. it was checked if values could be explained. There should be no unrealistic high or low values within the final data set) and vii) a sensitivity analysis was performed to explore the impact of the lost to follow up participants from the assumption made in the primary analysis (White et al. 2011). Therefore, the findings of the imputed data set were compared with an analysis of all randomised participants with complete values. Within the protocol a last observation carried forward analysis (LOCF) (Lachin 2016) was anticipated but this approach was not followed and is justified within the discussion section.

6.3 Results - LEArN trial - task procedure 1 - transfer procedure

6.3.1 Study population - task procedure 1

A convenience sample of 37 students (all potentially eligible students in year 3) on the BSc physiotherapy programme at UAS Valais were invited to participate in the study of task procedure 1. One student decided not to participate in the study (Figure 6.1) due to being physically not able to perform the procedure after a recent shoulder operation. Therefore, a sample of 36 participants were recruited for task procedure 1 of the LEArN trial (acquisition of a transfer procedure). Participants were randomised as follows: group 1A "MP" (n = 10); group 1B "nMP" (n = 8); group 1C "EFA" (n = 9) and group 1D "IFA" (n = 9).

All participants undertook the procedural skills training intervention and completed the post-acquisition test (T1) immediately after the intervention. The retention test (T2) was performed by 31 participants two weeks after the intervention. Five participants did not complete this endpoint. One participant was lost in group 1A and 1B respectively due to time constraints at point T2. In group 1C three participants were lost. Two participants were unable to perform the test because of injuries and one reported time constraints. All participants lost at the follow up endpoint allowed their T1 data to be used for analyses. Missing values at the retention test were obtained by multiple imputation. Imputations were performed in each group separately in order to follow the intention to treat principle.

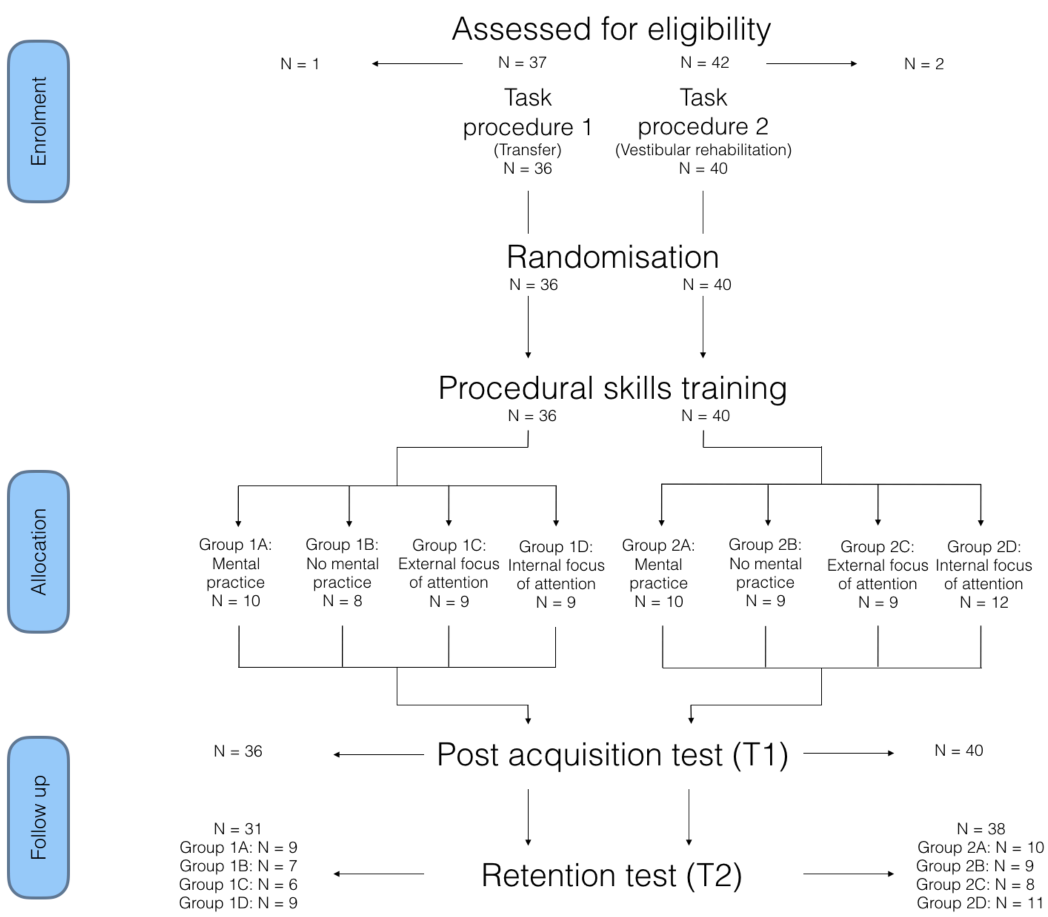


Figure 6.1 Study flow - task procedure 1 of the LEArN trial (i.e. "transfer procedure")

6.3.1.1 Participants - task procedure 1

Included participants are characterised in Table 6.2. Overall considerably more female and French speaking participants were included. However, this did not differ between groups with exception of group 1D with five female and four male participants. The age in all four group was around 23 years old. Previous academic performance was similar between groups. Marks in the Swiss educational system can range between 0 and 6 points. Higher scores indicate a better performance.

Table 6.2 Demographic and educational data of included participants - task procedure 1

Variable		Group 1A (n = 10)	Group 1B (n = 8)	Group 1C (n = 9)	Group 1D (n = 9)	Overall
Gender	female	8	5	8	5	26
	male	2	3	1	4	10
Primary language	Swiss French	8	5	8	6	27
	Swiss German	2	3	1	3	9
Age (years)	mean (SD)	23.7 (1.85)	23.5 (1)	23.2 (1.47)	22.9 (1.45)	23.4 (1.5)
	median (IQR)	23 (1.75)	23 (1.25)	22 (2)	22.5 (1.25)	23 (2)
Previous examinations (range 0-6)	mean (SD)	5.1 (0.34)	5.1 (0.3)	5 (0.3)	5.0 (0.24)	5 (0.31)
	median (IQR)	5.2 (0.48)	5.2 (0.55)	5.1 (0.3)	5 (0.35)	5.1 (0.5)

6.3.1.2 Data distribution

The data of participants in all four groups were assessed regarding their distribution in three steps: i) all groups showed signs of non-normality regarding skew and kurtosis, ii) density plots presented indications of non-normality of at least one group for each outcome measure (Appendix xi) and iii) the Shapiro-Wilk test was non-significant for the majority all outcome measures with exception of the self-reported confidence where one significant result was obtained (p: 0.001). However, based on the findings of the first and second step an informed decision was made to use non-parametric statistics for the analysis of effectiveness.

6.3.2 Comparison mental practice versus no mental practice

18 participants from the task procedure 1 cohort were randomised into the MP (n=10) and nMP (n=8) arms of the study and completed their specific procedural skills training and the post-acquisition test. Two participants (i.e. one in each group) did not perform the retention test.

6.3.2.1 Analysis of effectiveness

Within this section data related to the effectiveness of MP against nMP is presented (full data is available in Table 6.3).

Table 6.3 Effectiveness outcome data comparing MP (group 1A) against nMP (group 1B)

Outcome measure		Post-acquisition test (T1)			Retention test (T2)		
		Group 1A (n = 10) Mental practice	Group 1B (n = 8) No mental practice	Significance and effect size	Group 1A (n = 10) Mental practice	Group 1B (n = 8) No mental practice	Significance and effect size
APSPT 29 (0-116 points)	mean (SD)	76.3 (SD: 14.97)	73.13 (SD: 6.62)	W: 55, p: 0.2; r: -0.3	60 (SD: 14.13)	56.5 (SD: 14.37)	W: 49, p: 0.45; r: -0.17
	median (IQR)	81.5 (IQR: 14.75)	74 (IQR: 8.25)		62.5 (IQR: 5.75)	51.5 (IQR: 21)	
APSPT Subdimension PE (0-28 points)	mean (SD)	19.1 (SD: 5.43)	19.25 (SD: 1.83)	W: 43, p: 0.82 (*0.89); r: -0.05	13.5 (SD: 4.72)	12.86 (SD: 6.42)	W: 47, p: 0.56 (*0.7); r: -0.13
	median (IQR)	20 (IQR: 6)	19.5 (IQR: 2.5)		13.5 (IQR: 3.5)	10 (IQR: 10.5)	
PSC (0-24 points)	mean (SD)	20.9 (SD: 2.92)	19.25 (SD: 1.49)	W: 61, p: 0.06 (*0.3); r: -0.42	19 (SD: 6.11)	20 (SD: 3.7)	W: 39, p: 0.96 (*0.96); r: -0.01
	median (IQR)	21 (IQR: 2.75)	19.5 (IQR: 1)		21 (IQR: 3.5)	19.5 (IQR: 4.5)	
Response time (seconds)	mean (SD)	263.6 (SD: 70.3)	253 (SD: 37.19)	W: 50, p: 0.41 (*0.72); r: -0.19	300.2 (SD: 72.76)	284 (SD: 39.1)	W: 50, p: 0.4 (*0.7); r: -0.19
	median (IQR)	271.5 (IQR: 48.75)	255 (IQR: 28)		295 (IQR: 98.25)	282.5 (IQR: 24)	
Mental practice abilities (seconds)	mean (SD)	106.7 (SD: 62.27)	104.5 (SD: 91.41)	W: 42, p: 0.89 (*0.89); r: -0.03	186.3 (SD: 68.08)	160.25 (SD: 32.7)	W: 48, p: 0.5 (*0.7); r: -0.15
	median (IQR)	114 (IQR: 62.5)	86.5 (IQR: 165.75)		160 (IQR: 82)	161 (IQR: 52.75)	
Self-reported confidence (0-12 points)	mean (SD)	8.7 (SD: 0.95)	9.25 (SD: 1.49)	W: 31, p: 0.43 (*0.72); r: -0.18	7.2 (SD: 1.75)	8.25 (SD: 2.05)	W: 25.5, p: 0.21 (*0.7); r: -0.29
	median (IQR)	8.5 (IQR: 1)	9.5 (IQR: 2.25)		7 (IQR: 2.75)	8.5 (IQR: 2.25)	

Key. p: p-value, *p-value corrected for multiple testing; PE: procedure execution; PSC: Procedure specific checklist; r: effect size; W: Wilkinson rank-sum statistic

6.3.2.1.1 Assessment of procedural skills (APSPT 29)

At post-acquisition testing the MP group had a higher median score of 81.5 versus 74 for the nMP group. The difference was not statistically significant with a moderate effect size (r: - 0.3) in favour of MP. At the retention test both groups had reduced scores with the MP scored a median of 62.5 compared to 51.5 points in the nMP group. This difference represented a small effect (r: - 0.17) but was not statistically significant (Figure 6.2).

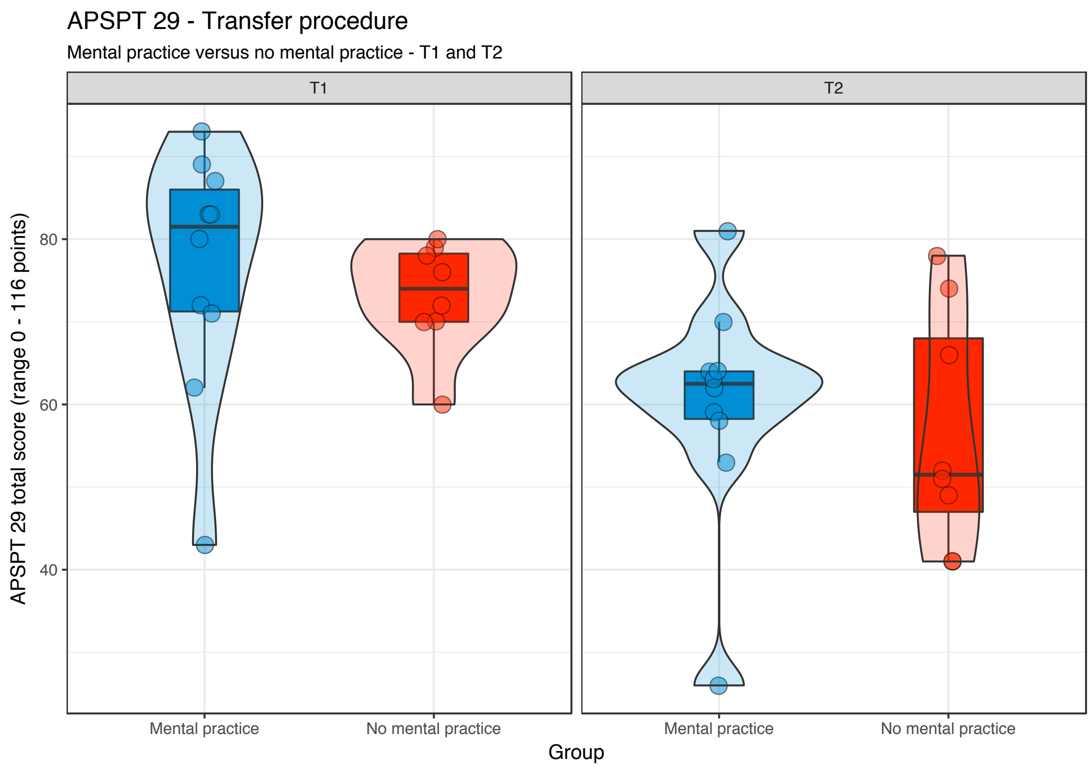


Figure 6.2 APSPT 29 - comparison MP (1A) versus nMP (1B). T1: post-acquisition test; T2: retention test

NB. Combined box - and violin plot with individual participant data plotted as dots. The density curve is presented as violin.

6.3.2.1.2 APSPT Sub-dimension procedure execution

The MP group had slightly higher median score of 20 versus 19.5 for the nMP group at post-acquisition testing (Figure 6.3). This between group difference was very small (r: - 0.05) and statistically not significant. At the retention test the difference increased to 3.5 points. The effect size remained small (r: - 0.13) and statistically not significant.

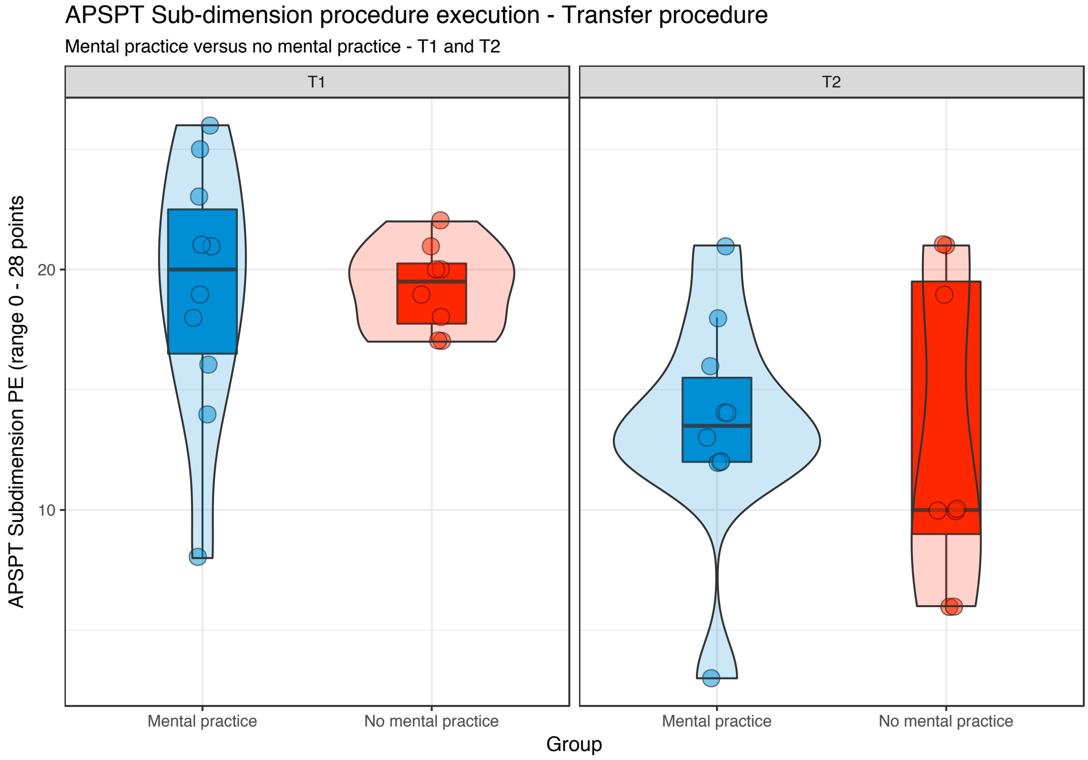


Figure 6.3 APSPT Sub-dimension procedure execution - comparison MP (1A) versus nMP (1B). T1: post-acquisition test; T2: retention test

6.3.2.1.3 Procedure specific aspects

The MP group scored on average 1.5 points higher on a PSC at the post-acquisition test (Figure 6.4). A medium to large effect size was analysed for this difference (r: - 0.42). This finding was not statistically significant.

The difference of mdn: 1.5 points in favour of the MP group on the PSC remained at the retention test. This difference was not statistically significant with an effect size of r: - 0.01.

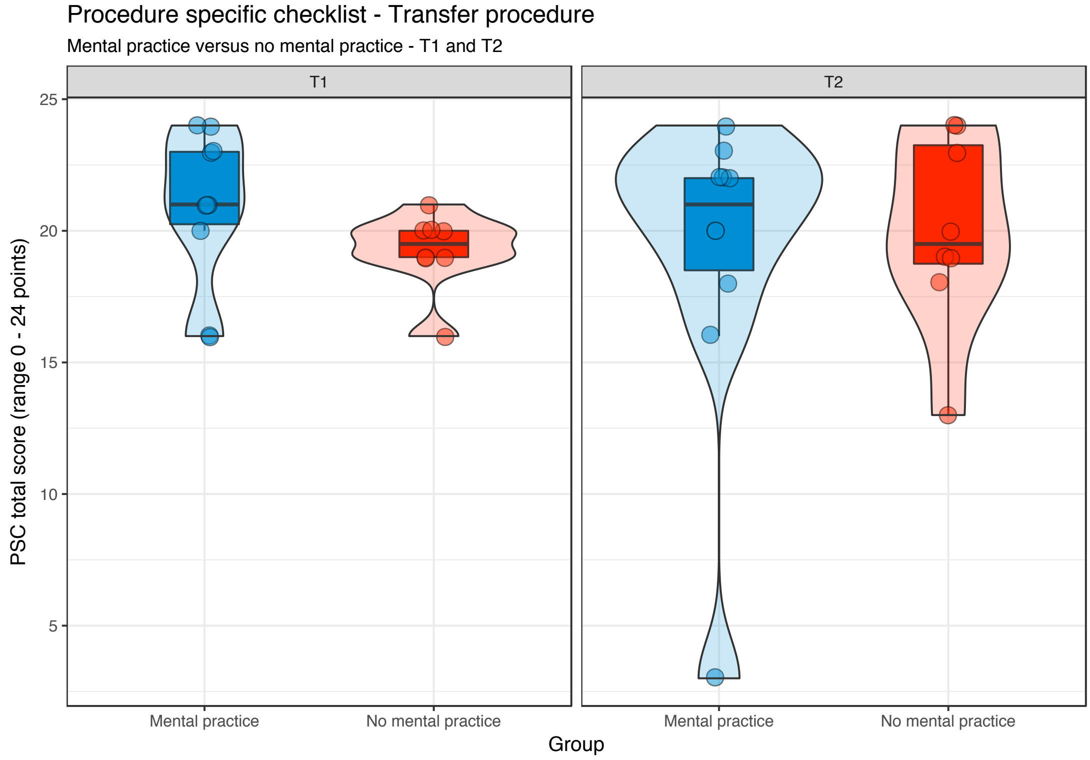


Figure 6.4 PSC - comparison MP (1A) versus nMP (1B). T1: post-acquisition test; T2: retention test

6.3.2.1.4 Response time

The median response time was longer in the MP group compared to the nMP group (mdn: 271.5 versus 255 sec) at post-acquisition testing. This difference represented a moderate effect (r: -0.19) but was not statistically significant. This did not change at the retention test and both groups had slightly increased times. A median response time of 295 seconds in the MP group compared to 282.5 seconds in the nMP was analysed (Figure 6.5). The effect size remained moderate (r: - 0.19) and findings were statistically not significant.

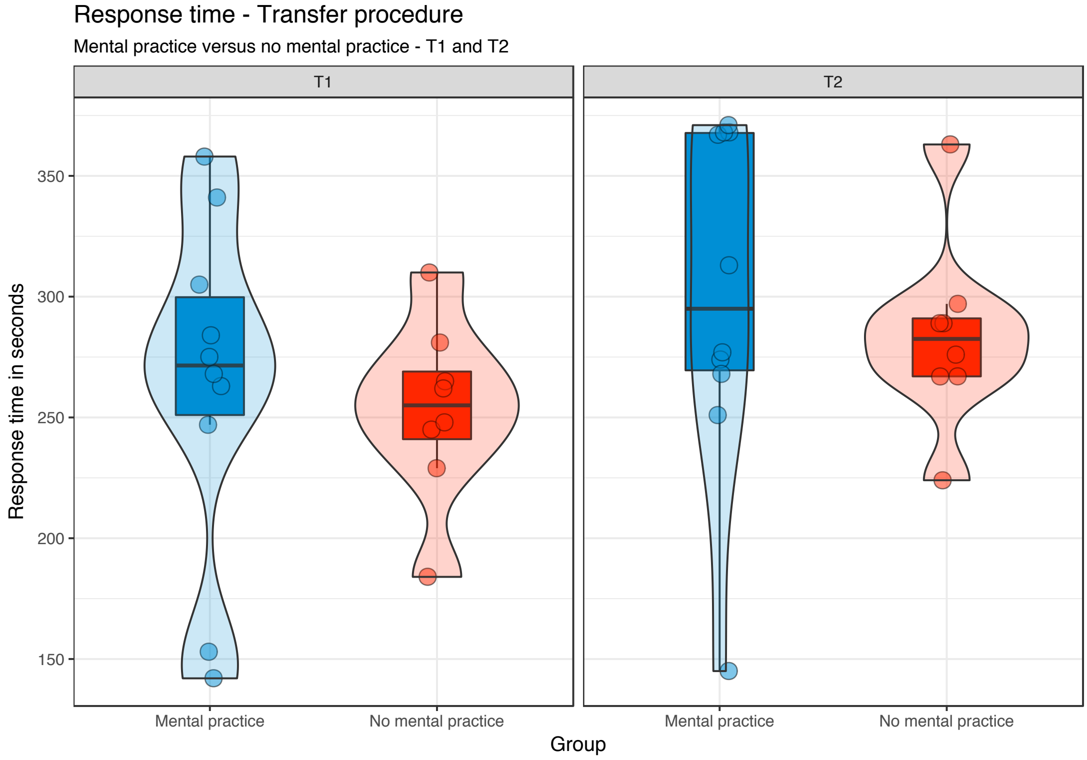


Figure 6.5 Response time - comparison MP (1A) versus nMP (1B). T1: post-acquisition test; T2: retention test

6.3.2.1.5 Mental practice abilities

MP abilities were measured with a mental chronometry approach. The physical response time was compared to the time participants needed to perform the procedure mentally. Participants in MP group had a higher difference (mdn: 114 seconds) between physical and mental time compared to the participants in the nMP group (mdn: 86.5 seconds) at the post-acquisition test. The difference was statistically not significant (Figure 6.6).

At the retention test the performance was similar between groups (mdn: 160 seconds for MP versus mdn: 161 seconds for nMP). The findings were statistically not significant. A small to medium effect size of r: - 0.15 was observed in favour of the nMP.

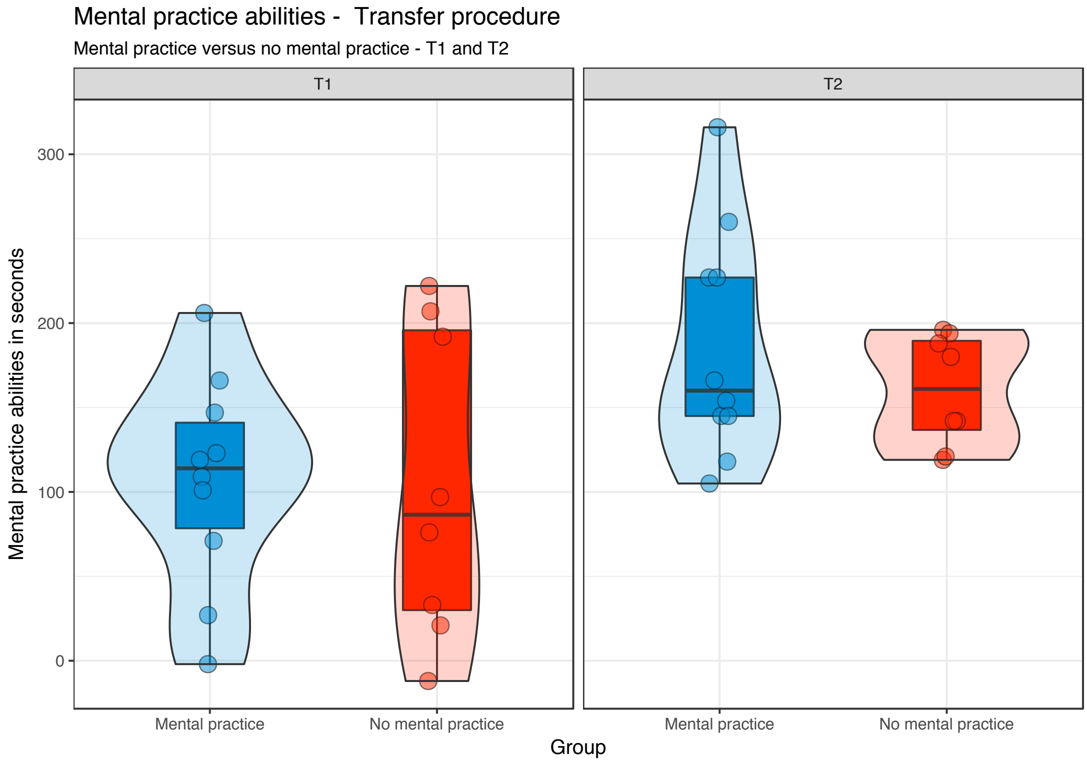


Figure 6.6 Mental practice abilities - comparison MP (1A) versus nMP (1B). T1: post-acquisition test; T2: retention test

NB. more seconds relate to a greater difference between physical and mental response time (i.e. a better performance scores lower).

6.3.2.1.6 Self-reported confidence

The nMP had a higher median score of 9.5 versus 8.5 points for the MP group at post-acquisition testing (Figure 6.7). This represented a small effect size (r: - 0.18) but was not statistically significant.

A median of 7 points in MP versus of 8.5 for the nMP group were recorded at retention testing. The difference was not statistically significant and represented a medium effect size in favour of the nMP group (r: - 0.29).

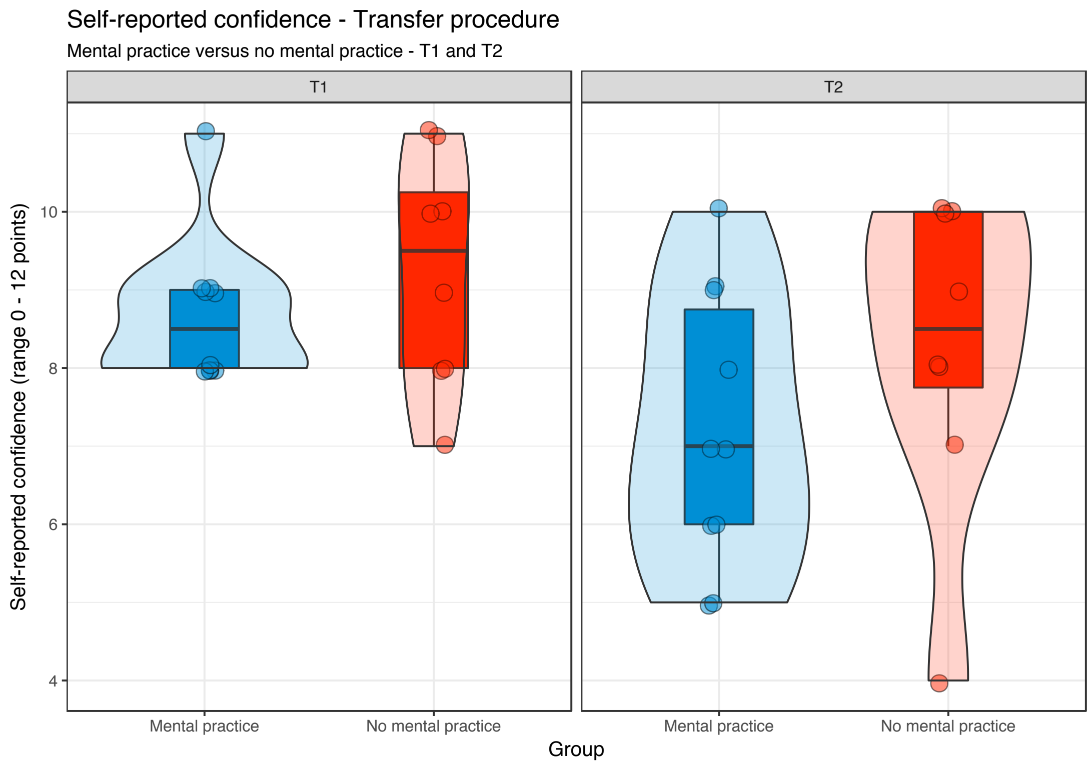


Figure 6.7 Self-reported confidence - comparison MP (1A) versus nMP (1B). T1: post-acquisition test; T2: retention test

6.3.2.2 Analysis of the feasibility

6.3.2.2.1 Recruitment rate

37 persons were invited to participate in this study, with a total of 36 being recruited. This resulted in a recruitment rate of 97.3%.

6.3.2.2.2 Failure rate

At the post-acquisition endpoint one MP participant was classified as "failed to perform" the procedure (Table 6.4). This equates to a 10% failure rate in the MP group. This was considerably below the predefined threshold of 40%. At the retention test failures were observed in both groups. This resulted in failure rates of 11.1% (1/9) in the MP and 14.3% (1/7) in the nMP group.

Table 6.4 Failure rate - comparison MP (group 1A) versus nMP (group 1B)

T1	Group 1A (MP)	Group 1B (nMP)	T2	Group 1A (MP)	Group 1B (nMP)
Failed to perform	1	0	Failed to perform	1	1
Performed procedure	9	8	Performed procedure	8	6

NB. Missing values for participants at the retention test were not imputed. Within the table only complete cases are presented.

6.3.2.2.3 Feasibility of the procedural skills training session

The time needed to provide the instructions was similar in both groups (i.e. 28 minutes for the MP and 25 minutes for the nMP group). After 1 hour all participants finished the practice sessions in both groups.

Within the protocol it was assumed that the MP intervention might be difficult to use for the procedural skills training as it is not a standard intervention. Participants were given explanation regarding how to perform the MP. During the practice, no further questions were asked and on checking, all participants indicated that they could perform the MP instructions.

The most frequently reported challenges in the MP group were related to i) the hand placement during the procedure and ii) memorisation processes. Specifically, it was mentioned that the relatively large number of cues was challenging to memorise. Most challenges in the nMP group were related to i) ergonomic aspects of the procedure, ii) the hand placement and the security of the patient. All identified challenges are presented in Table 6.5.

Table 6.5 Identified challenges and problems - comparison MP (group 1A) versus nMP (group 1B)

Challenges & problems	Group 1A (MP)	Group 1B (nMP)
Communication	1	0
Ergonomic aspects	0	2
Hand placement	3	2
Memory	3	0
Peer learning	0	1
Preparation	1	0
Security	1	2
Simulation	1	0
Specific procedure parts	2	0

6.3.2.2.4 Feasibility of the outcome assessment

27 minutes were needed to evaluate each video recording by the independent physiotherapist. In total 37 participants were evaluated at the post-acquisition test (i.e. 16 h 49 min). For the retention test 31 video recording were evaluated, which required 13h and 57 min to complete.

Regarding the reliability of the equipment no problems were identified (i.e. no video recording was lost during the whole process). The camera was appropriately positioned to evaluate the performance of the participants during this procedure. The audio recordings provided more challenges. It was difficult to correctly evaluate two audio recordings because the participants spoke very quietly.

During outcome assessment, the PSC measurement instrument could be scored relatively fast. In contrast, more challenges were reported using the APSPT 29, which required more time and cognitive effort to administer.

6.3.2.2.5 Sample size

The effect sizes for the outcomes “procedural performance” measured with the APSPT 29 and the “procedural specific aspects” measured with the PSC were used to calculate the sample size of a larger follow-up study (Faul et al. 2007).

At post-acquisition testing an effect size of r: - 0.3 was measured in favour of the MP group. For the power calculation, a two-tailed test with the error probability α of 0.05 and the power of 0.95 was set. These parameters predicted that a total sample size of 140 participants (i.e. 70 in each group) would be required in a future study.
A second power analysis was performed with the PSC outcome data. The effect size in favour of the MP group measured with a PSC was r: - 0.42. Due to the larger effect size the required sample size decreased to 66 participants with 33 participants required for each group.

6.3.2.2.6 Miscellaneous aspects

Two miscellaneous feasibility items are presented below. These were common mistakes, which occurred during the performance of the procedure and the loss to follow up rate at the retention test.
Analysis of common mistakes showed that the procedure parts in the MP group with lowest performance were step 4 “move into a 4-foot position”, step 8 “returning into the 4-foot position” and step 9 “move into a knee-standing position”. Common mistakes during step 4 were i) insufficient trunk support during the forward movement of the patient and ii) insufficient support of the weaker shoulder during weight-bearing. The following mistakes were observed while performing step 8: i) problems anticipating the patient’s movement during this step and ii) insufficient support of the patient’s hips and shoulder. During step 9 (i.e. the transition from 4-foot standing into knee-standing) some participants blocked the patient’s hip movement and therefore the patient could not reach the final position.
Procedure parts in the nMP group with the lowest performance were step 4 “move into a 4-foot position” and step 5 “patient is asked to sit on the side”. During step 4 the same mistakes presented above were observed. Performing step 5 some participants showed these mistakes: i) insufficient trunk support and ii) the movement was performed relatively fast, which might cause injuries to the patient.
In addition, this group scored low on the procedure preparation item. Indicating that instructions were omitted or only briefly presented.

Two participants were lost to follow up at the retention test (i.e. each group lost one participant). This caused a loss to follow up of 10% in the MP group and 12.5% in the nMP group. Both participants were lost because of time constraints.

6.3.3 Comparison external focus of attention versus internal focus of attention

18 participants from the task procedure 2 cohort were randomised into EFA (n=9) and IFA (n=9) arms of the study and completed their specific procedural skills training and the post-acquisition test. Three participants in the EFA group did not perform the retention test.

6.3.3.1 Analysis of effectiveness

Within this section data related to the effectiveness of EFA against IFA is presented. (full data is available in Table 6.6).

Table 6.6 Effectiveness outcome data comparing an EFA (group 1C) versus an IFA (group 1D)

Outcome measure		Post-acquisition test (T1)			Retention test (T2)		
		Group 1C (n = 9) External focus of attention	Group 1D (n = 9) Internal focus of attention	Significance and effect size	Group 1C (n = 9) External focus of attention	Group 1D (n = 9) Internal focus of attention	Significance and effect size
APSPT 29 (0-116 points)	mean (SD)	69 (SD: 8.29)	79.22 (SD: 11)	W: 17, p: 0.04; r: -0.44	45 (SD: 12.06)	60.22 (SD: 16.38)	W: 19, p: 0.06; r: -0.41
	median (IQR)	70 (IQR: 6)	81 (IQR: 10)		43 (IQR: 16)	52 (IQR: 25)	
APSPT Subdimension PE (0-28 points)	mean (SD)	16.44 (SD: 2.24)	20.55 (SD: 3.09)	W: 12.5, p: 0.01 (*0.02); r: -0.53	8.89 (SD: 3.62)	13 (SD: 5.43)	W: 24.5, p: 0.15 (*0.3); r: -0.31
	median (IQR)	17 (IQR: 2)	21 (IQR: 2)		8 (IQR: 2)	10 (IQR: 8)	
PSC (0-24 points)	mean (SD)	19.11 (SD: 1.45)	21.889 (SD: 1.54)	W: 6.5, p: 0.002 (*0.01); r: -0.66	15.67 (SD: 3.71)	18.44 (SD: 5.43)	W: 23.5, p: 0.14 (*0.3); r: -0.32
	median (IQR)	19 (IQR: 1)	22 (IQR: 1)		15 (IQR: 3)	20 (IQR: 5)	
Response time (seconds)	mean (SD)	294. 67 (SD: 76.74)	285.11 (SD: 47.21)	W: 42, p: 0.93 (*0.93); r: -0.02	307.78 (SD: 56.3)	287.33 (SD: 37.98)	W: 46, p: 0.66 (*0.66); r: -0.1
	median (IQR)	255 (IQR: 113)	290 (IQR: 56)		279 (IQR: 79)	285 (IQR: 42)	
Self-reported confidence (0-12 points)	mean (SD)	9.67 (SD: 2)	8 (SD: 1.12)	W: 61, p: 0.06 (*0.09); r: -0.4	7.11 (SD: 1.9)	6.33 (SD: 2.45)	W: 48, p: 0.53 (*0.66); r: -0.14
	median (IQR)	9 (IQR: 3)	8 (IQR: 2)		7 (IQR: 2)	6 (IQR: 3)	

Key. p: p-value, *p-value corrected for multiple testing; PE: procedure execution; PSC: Procedure specific checklist; r: effect size; W: Wilkinson rank-sum statistic

6.3.3.1.1 Assessment of procedural skills (APSPT 29)

The IFA group (mdn: 81) performed considerably better than the EFA group (mdn: 70) at the post-acquisition test (Figure 6.8). This represented a medium to large effect size of r: - 0.44. This finding was statistically significant (p: 0.04).

Both groups showed a decreased performance at the retention test. The difference remained in favour of the IFA group (mdn: 52 versus 43 points in the EFA group). The effect size in favour of the IFA group remained medium to large (r: -0.41) but was statically not significant.

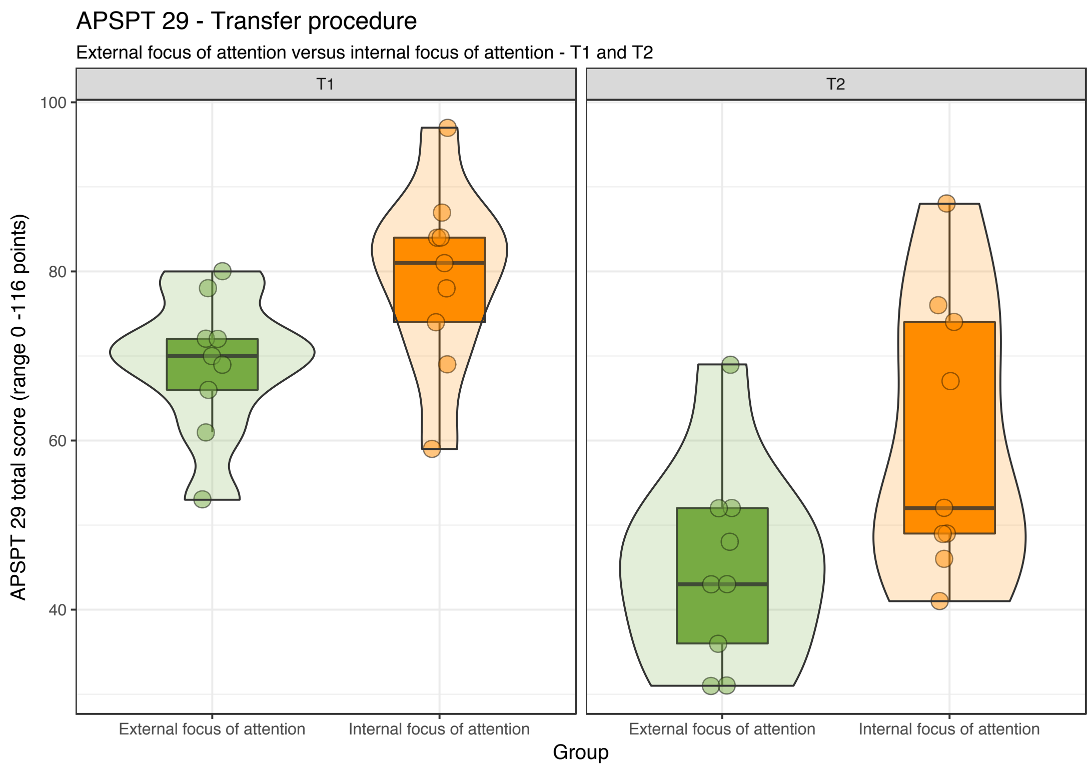


Figure 6.8 APSPT 29 - comparison EFA (1C) versus IFA (1D). T1: post-acquisition test; T2: retention test

6.3.3.1.2 APSPT Sub-dimension procedure execution

The median "procedure execution" was higher in the IFA group at post-acquisition testing (mdn: 21 versus 17 points for an EFA). This difference represented a large effect (r: -0.53) and was statistically significant (p: 0.02).

The median performance in the IFA group remained superior to the EFA group (mdn: 10 points versus mdn of 8 points) at the retention test (Figure 6.9). This difference was associated with a medium effect size (r: - 0.31) and was not statistically significant.

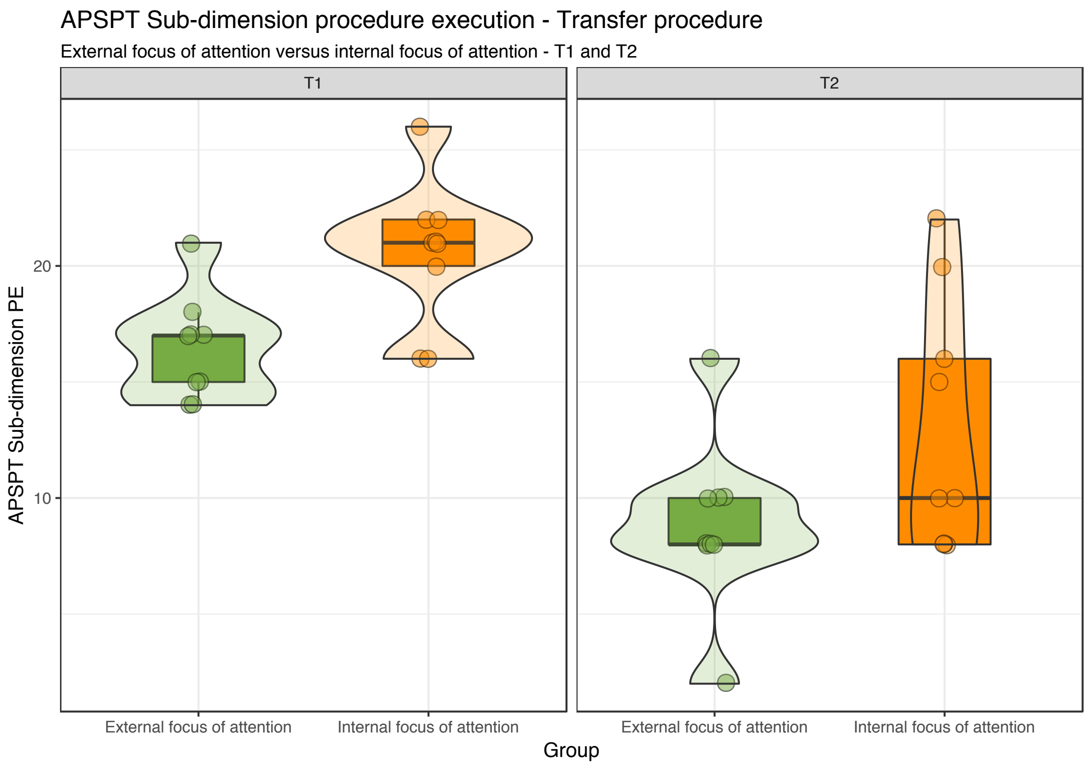


Figure 6.9 APSPT Sub-dimension procedure execution - comparison EFA (1C) IFA (1D). T1: post-acquisition test; T2: retention test

6.3.3.1.3 Procedure specific aspects

The IFA group had a higher performance measured with a PSC (mdn: 22 points) versus 19 points for the EFA group at post-acquisition testing (Figure 6.10). This difference of three points was associated with a large effect (r: - 0.66) and was statistically significant (p: 0.002 and p: 0.01 after correction for multiple testing). The results remained in favour of the IFA group at retention testing (mdn: 20 for the IFA versus mdn: 15 points for the EFA group). This difference was not statistically significant but a medium effect size in favour of the IFA group was analysed (r: - 0.32).

Figure 6.10 PSC - comparison EFA (1C) versus IFA (1D). T1: post-acquisition test; T2: retention test

6.3.3.1.4 Response time

The IFA group needed on average more time to perform the procedure (mdn: 285 seconds) compared to the EFA group (mdn: 279 seconds) at the post-acquisition test (Figure 6.11). The difference was statistically not significant with a very low effect size (r: - 0.02).

At the retention test the shorter median response time for the EFA group remained (mdn: 279 versus a mdn of 285 seconds for the IFA group). The finding was not statistically significant. A small effect size in favour of the EFA group was analysed (r: - 0.1).

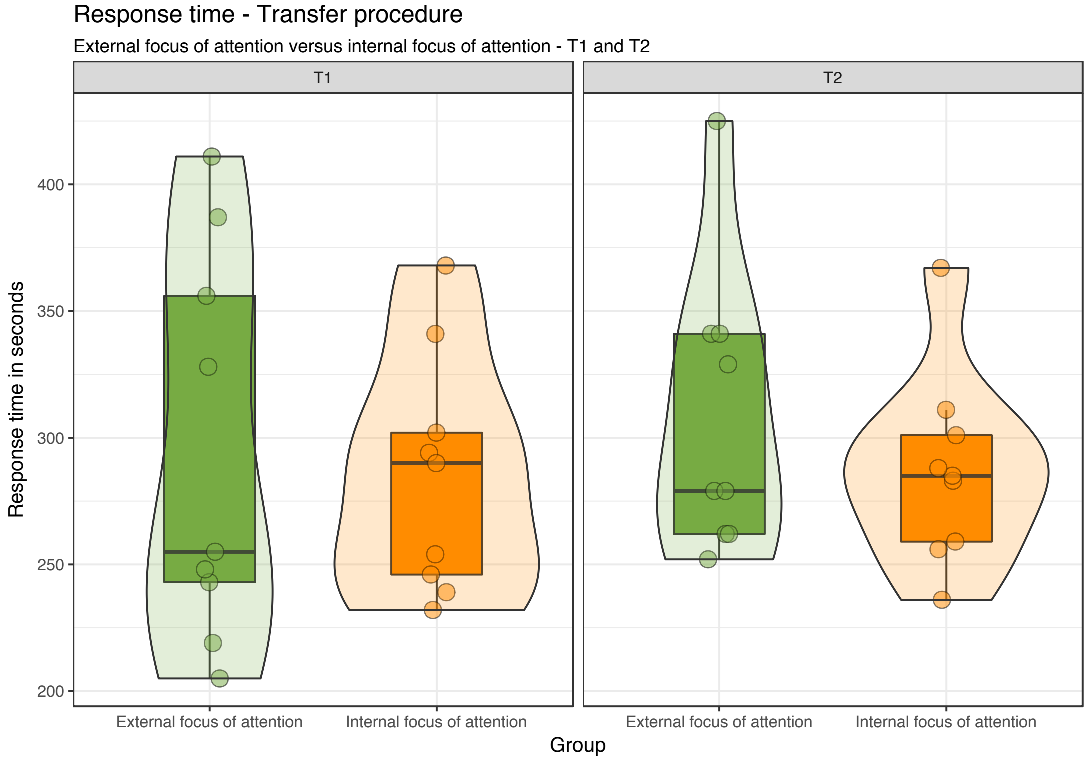


Figure 6.11 Response time - comparison EFA (1C) versus IFA (1D). T1: post-acquisition test; T2: retention test

6.3.3.1.5 Self-reported confidence

The median self-reported confidence was higher in the EFA group at the post-acquisition test (mdn: 9.67 points) compared 8 points in the IFA group (Figure 6.12). This difference was analysed as moderate to large effect size (r: - 0.4) but was not statistically significant. At the retention test the median self-reported confidence remained higher in the EFA group (mdn: 7 points) compared to 6 points in the IFA group. This was associated with a small effect size (r: - 0.14). The findings were statistically not significant.

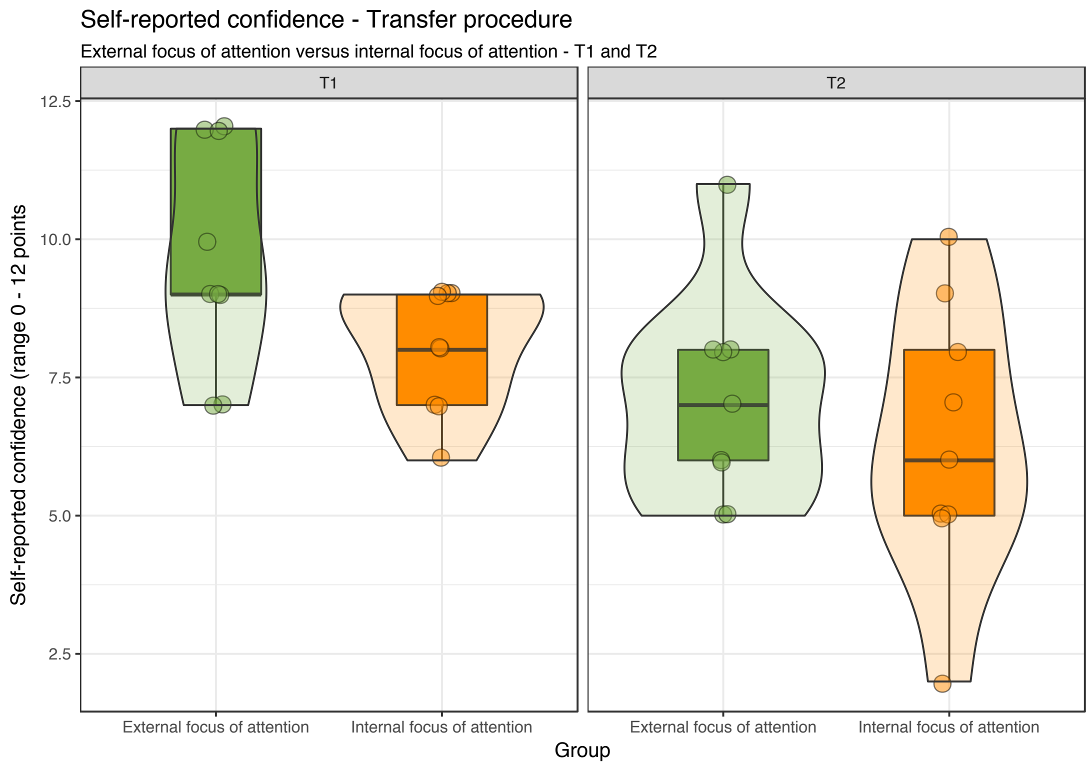


Figure 6.12 Self-reported confidence - comparison EFA (1C) versus IFA (1D). T1: post-acquisition test; T2: retention test

6.3.3.2 Analysis of the feasibility

Below feasibility criteria are evaluated for the comparison EFA versus IFA group. Two of the feasibility criteria relate to the complete study of task procedure 1 - transfer. These are the recruitment rate and the feasibility of the outcome assessment. Both have already been presented in section 6.3.2.2 and are not repeated within this section.

6.3.3.2.1 Failure rate

A failure rate of 0% was analysed in both groups at post-acquisition testing (Table 6.7). At the retention test the failure rate increased to 33.33% (2/6) in the EFA group and 22.22% (2/9) in the IFA group.

Table 6.7 Failure rate - comparison EFA (1C) versus IFA (1D)

T1	Group 1C (EFA)	Group 1D (IFA)	T2	Group 1C (EFA)	Group 1D (IFA)
Failed to perform	0	0	Failed to perform	2	2
Performed procedure	9	9	Performed procedure	4	7

NB. Missing values for participants at the retention test (T2) endpoint were not imputed. Within the table only complete cases are presented.

6.3.3.2.2 Feasibility of the procedural skills training session

The main feasibility issue for the educator was to avoid mistakes during instructions and feedback with regard to the used FoA. The procedural skills training sessions were recorded and analysed for mistakes that occurred during the sessions. The analysis did not find any mistakes during the instructions. Difficulties were identified regarding the feedback part of the procedural skills training sessions. Especially, participants in the EFA group asked questions regarding the placement of the therapist's body parts (e.g. "where exactly should I place my hands to stabilise the shoulder").

The time needed for instructions was 25 minutes in the EFA group versus 29 minutes in the IFA group. All participants indicated after 1 hour that they did not need more time to practice.

The most frequent reported challenges by participants in the EFA group was the hand placement and the communication with the patient. Participants form the IFA group reported similar challenges with the hand placement but also mentioned that the simulation of the patient during practice was difficult (Table 6.8).

Table 6.8 Identified challenges and problems - comparison EFA (1C) versus IFA (1D).

Challenges & problems	Group 1C (EFA)	Group 1D (IFA)
Communication	4	1
Ergonomic aspects	0	1
Hand placement	5	5
Memory	1	2
Peer learning	1	0
Preparation	0	0
Security	1	1
Simulation	0	4
Specific procedure parts	1	0

6.3.3.2.3 Sample size

For the APSPT 29 a moderate to large effect size of r: - 0.44 in favour of the IFA group was analysed at post-acquisition testing. For the power calculation, a two-tailed test with the error probability α of 0.05 and the power of 0.95 was set. This resulted in a sample size of 60 participants (i.e. 30 in each group) for the comparison EFA versus IFA practice.

The PSC showed a very large effect size in favour of the IFA group at post-acquisition testing (r: - 0.66). This resulted in a sample size of 20 participants with 10 participants required for each group.

6.3.3.2.4 Miscellaneous aspects

Two miscellaneous feasibility items are presented below. These were common mistakes, which occurred during the performance of the procedure and the loss to follow up rate at the retention test.

Common mistakes in this group occurred during the same procedure steps as presented above for the comparison MP versus nMP (i.e. procedure step 4 and 8). But the mistakes differed regarding one aspect. The participants had problems with the placement of their hands and body parts and a wide variety of movement strategies were observed, which led to i) insufficient trunk support and ii) insufficient support of the weaker shoulder in step 4. For step 8 observed common mistakes were i) problems anticipating the patient's movement and ii) insufficient support of the patient's hips and shoulder.

Evaluation of the performance in the IFA group indicated that the average performance of each procedure step was relatively high and no common mistakes were analysed.

One feasibility issue was that three participants were lost to follow up at the retention test. This led to a loss to follow up rate of 33% in the EFA group.

6.3.3.3 Sensitivity analysis 1 - imputation method- comparison mental practice (1A) versus no mental practice (1B)

This sensitivity analysis compared the findings generated with a MI approach with an analysis using only data of all observed participants (CC: complete case) at the retention test.

The median score and effect size of the primary outcome (APSPT 29) remained in favour of the MP group and findings did not reach the level of statistical significance (p: 0.68 CC versus p: 0.45 MI). This was also observed for the secondary outcome measures (Table 6.9). The observed median scores and effect sizes remained in favour of the group analysed in the primary analysis (MI) and statistical significance did not change between the primary and sensitivity analysis. However, the effect sizes changed their magnitude. The greatest change was observed for the outcome "mental practice abilities" (r: - 0.02 CC versus - 0.15 MI).

6.3.3.4 Sensitivity analysis 2 - imputation method - comparison external focus of attention (1C) versus internal focus of attention (1D)

In both analyses the point estimates of the primary outcome "APSPT 29" were in favour of the IFA group. A medium effect size (r: - 0.33) was observed in the CC analysis, which changed to medium to large with the MI approach (r: - 0.41). The findings remained statistically not significant.

All secondary outcome measures showed the same group superiority identified in the primary analysis to be present in the CC analysis. Statistical significance and effect sizes varied between the analyses but changes were relatively small (Table 6.10).

6.3.3.5 Sensitivity analysis 3 - correlation response time and procedure performance

This sensitivity analysis was performed to investigate the association between response time and procedure performance measured with the APSPT 29 and the PSC.

The response time was not significantly correlated with the APSPT 29 total score, r_s: 0.03, p: 0.76. The performance measured with the PSC was also not significantly correlated with response time, r_s: 0.16, p: 0.1.

Table 6.9 Sensitivity analysis - exploring the effect of the multiple imputation approach – comparison MP (group 1A) versus nMP (group 1B)

Outcome measure		Retention test (T2) (CCA) Group 1A (n = 9) Mental practice	Retention test (T2) (CCA) Group 1B (n = 7) No mental practice	Retention test (T2) (CCA) Significance and effect size	Retention test (T2) (MI) Group 1A (n = 10) Mental practice	Retention test (T2) (MI) Group 1B (n = 8) No mental practice	Retention test (T2) (MI) Significance and effect size
APSPT 29 (0-116 points)	mean (SD)	59.56 (SD: 14.91)	58.71 (SD: 13.97)	W: 36, p: 0.68; r: -0.09	60 (SD: 14.13)	56.5 (SD: 14.37)	W: 49, p: 0.45; r: -0.17
	median (IQR)	62 (IQR: 6)	52 (IQR: 20)		62.5 (IQR: 5.75)	51.5 (IQR: 21)	
APSPT Subdimension PE (0-28 points)	mean (SD)	13.44 (SD: 5)	13.86 (SD: 6.26)	W: 34, p: 0.83 (*0.9); r: -0.05	13.5 (SD: 4.72)	12.86 (SD: 6.42)	W: 47, p: 0.56 (*0.7); r: -0.13
	median (IQR)	13 (IQR: 4)	10 (IQR: 10)		13.5 (IQR: 3.5)	10 (IQR: 10.5)	
PSC (0-24 points)	mean (SD)	18.67 (SD: 6.38)	20.14 (SD: 3.98	W: 28, p: 0.75 (*0.9); r: -0.07	19 (SD: 6.11)	20 (SD: 3.7)	W: 39, p: 0.96 (*0.96); r: -0.01
	median (IQR)	20 (IQR: 4)	20 (IQR: 5)		21 (IQR: 3.5)	19.5 (IQR: 4.5)	
Response time (seconds)	mean (SD)	292.67 (SD: 72.88)	286.43 (SD: 41.58)	W: 35, p: 0.75 (*0.9); r: -0.07	300.2 (SD: 72.76)	284 (SD: 39.1)	W: 50, p: 0.4 (*0.7); r: -0.19
	median (IQR)	277 (IQR: 99)	289 (IQR: 21.5)		295 (IQR: 98.25)	282.5 (IQR: 24)	
Mental practice abilities (seconds)	mean (SD)	181.78 (SD: 70.59)	162.86 (SD: 34.41)	W: 33, p: 0.92 (*0.9); r: -0.02	186.3 (SD: 68.08)	160.25 (SD: 32.7)	W: 48, p: 0.5 (*0.7); r: -0.15
	median (IQR)	154 (IQR: 82)	180 (IQR: 59.5)		160 (IQR: 82)	161 (IQR: 52.75)	
Self-reported confidence (0-12 points)	mean (SD)	7.22 (SD: 1.86)	8 (SD: 2.08)	W: 23.5, p: 0.42 (*0.9); r: -0.18	7.2 (SD: 1.75)	8.25 (SD: 2.05)	W: 25.5, p: 0.21 (*0.7); r: -0.29
	median (IQR)	7 (IQR: 3)	8 (IQR: 2)		7 (IQR: 2.75)	8.5 (IQR: 2.25)	

Key. CCA: complete case analysis; MI: multiple imputation analysis; p: p-value, *p-value corrected for multiple testing; PE: procedure execution; PSC: Procedure specific checklist; r: effect size; W: Wilkinson rank-sum statistic

Table 6.10 Sensitivity analysis –exploring the effect of the multiple imputation approach – comparison EFA (group 1C) versus IFA (group 1D)

Outcome measure		Retention test (T2) (CCA)			Retention test (T2) (MI)		
		Group 1C (n = 6) External focus of attention	Group 1D (n = 9) Internal focus of attention	Significance and effect size	Group 1C (n = 9) External focus of attention	Group 1D (n = 9) Internal focus of attention	Significance and effect size
APSPT 29 (0-116 points)	mean (SD)	46.5 (SD: 13.43)	60.22 (SD: 16.38)	W: 13.5, p: 0.12; r: -0.33	45 (SD: 12.06)	60.22 (SD: 16.38)	W: 19, p: 0.06; r: -0.41
	median (IQR)	45.5 (IQR: 13.25)	52 (IQR: 25)		43 (IQR: 16)	52 (IQR: 25)	
APSPT Subdimension PE (0-28 points)	mean (SD)	8.67 (SD: 4.5)	13 (SD: 5.43)	W: 15, p: 0.15 (*0.46) ; r: -0.3	8.89 (SD: 3.62)	13 (SD: 5.43)	W: 24.5, p: 0.15 (*0.3); r: -0.31
	median (IQR)	8 (IQR: 1.5)	10 (IQR: 8)		8 (IQR: 2)	10 (IQR: 8)	
PSC (0-24 points)	mean (SD)	15.5 (SD: 4.55)	18.44 (SD: 5.43)	W: 16.5, p: 0.23 (*0.5); r: -0.26	15.67 (SD: 3.71)	18.44 (SD: 5.43)	W: 23.5, p: 0.14 (*0.3); r: -0.32
	median (IQR)	15 (IQR: 5.25)	20 (IQR: 5)		15 (IQR: 3)	20 (IQR: 5)	
Response time (seconds)	mean (SD)	314.67 (SD: 64.88)	287.33 (SD: 37.98)	W: 32, p: 0.6 (*0.6); r: -0.11	307.78 (SD: 56.3)	287.33 (SD: 37.98)	W: 46, p: 0.66 (*0.66); r: -0.1
	median (IQR)	304 (IQR: 71.75)	285 (IQR: 42)		279 (IQR: 79)	285 (IQR: 42)	
Self-reported confidence (0-12 points)	mean (SD)	7.5 (SD: 2.07)	6.33 (SD: 2.45)	W: 34.5, p: 0.4 (*0.53); r: -0.18	7.11 (SD: 1.9)	6.33 (SD: 2.45)	W: 48, p: 0.53 (*0.66); r: -0.14
	median (IQR)	7.5 (IQR: 1.75)	6 (IQR: 3)		7 (IQR: 2)	6 (IQR: 3)	

Key. CCA: complete case analysis; MI: multiple imputation analysis; p: p-value, *p-value corrected for multiple testing; PE: procedure execution; PSC: Procedure specific checklist; r: effect size; W: Wilkinson rank-sum statistic

6.4 Discussion - LEArN trial - task procedure 1 - transfer procedure

The discussion is structured within three sections. First, findings of the comparison MP versus nMP are discussed. Then, the comparison EFA versus IFA is discussed and lastly general limitations are discussed.

6.4.1 Discussion comparison mental practice versus no mental practice

6.4.1.1 Discussion of the effectiveness

The comparison of MP versus nMP was not statistically significant and therefore it is not possible to state that MP was superior to nMP. However, a possible small trend in favour of the MP group was observed regarding the primary outcomes measure APSPT 29 at post-acquisition testing. That is the point estimate and the effect size were both in favour of the MP group. The same possible trend was found on a PSC. Despite not being statistically significant this might indicate that the use of MP can possibly increase the performance after a procedural skills training in physiotherapy education. However, this remains speculative as the findings were not statistically significant. This finding is supported by evidence from other studies in HPE. For example, the meta-analysis published by Sattelmayer et al. (2016a) found a moderate effect size of 0.43 SMD's in favour of a MP intervention at post-acquisition testing. Effect sizes for individual studies ranged from -0.09 (Sanders et al. 2008) to 1.80 SMD (Arora et al. 2011). This shows that the findings of this study are similar to results presented by other studies in related disciplines (such as Geoffrion et al. 2012).

Furthermore, of the five studies included into the meta-analysis only one study showed statistically significant results (Arora et al. 2011). The effect size of the current study was considerable lower and more in line with the findings of the remaining four studies (Sanders et al. 2004; Sanders et al. 2008; Komesu et al. 2009; Geoffrion et al. 2012).

The observed point estimate and the effect size of the APSPT 29 at the retention test remained in favour of the MP group. However, in the presence of the non-significance and the small effect size it is not possible to state that learning in this group was superior.

Only two studies were found using a transfer test to make inferences on learning in HPE (Sanders et al. 2004; Sanders et al. 2008). Findings of the studies were pooled in the above mentioned meta-analysis and a small effect size in favour of MP at transfer tests was identified. This is similar to the findings of this study.

No statistically significant results were identified on the outcome “response time”. However, the observed point estimates of the response time indicated a trend that participants in the MP group needed more time to perform the procedure compared to participants in the other group. Based on findings from other studies and on literature recommendations (Magill and Anderson 2014) the response time is expected to decrease with increasing proficiency. In this study, the group with the higher performance metrics needed more time to perform the procedure. A priori it was assumed that controlling a patient during the transfer represents an unstable system and the therapists needs to balance this system. Therefore, it was assumed that spending less time in in unstable positions would result in a shorter response time duration but the opposite was observed. Several factors might explain this finding: i) participants in the MP group spent more time in relatively safe positions. The transition between two procedure steps was performed relatively fast (e.g. moving from a 4-foot position into a knee-standing position) and a rest period was instructed in the new position, ii) more weight-bearing exercises were performed, iii) the patients were instructed to perform small movements to explore their limits of stability during each step of the procedure and iv) the response time was not only related to motor behaviour in this study. Next to the speed of the therapeutic motor skills there are other factors, which can cause a longer response time (e.g. providing more instructions and an increased preparation time prior to the procedure).

A sensitivity analysis was performed to investigate the association between the variables response time and procedural performance (APSPT 29 and PSC). Findings showed no significant correlation between response time and procedural performance. However, a trend towards significance was observed between PSC and response time indicating that a longer duration was associated with a better performance.

The MP abilities measured with a mental chronometer approach (Jeannerod 1995) were not superior in the MP group. The participants in both groups performed the procedure mentally in absence of a movement and the time they needed for the mental performed procedure was compared to the physical response time. Research suggested that with growing proficiency a temporal equivalence between physical and mental time is achieved (Unestahl 1983). It was expected that MP could have a positive influence on this result. Such an effect was not observed. This could be due to the fact that the amount of MP was not sufficient to show an effect.

For example, studies showing an improved motor performance used more repetitions than the participants in the LEArN trial. Jackson et al. (2003) used 1500 mental repetitions over a 5 day acquisition period and Allami et al. (2008) showed that healthy participants required 120 mental practice trials for skill acquisition. Considerably less MP repetitions were performed in the LEArN trial and this has probably decreased skill acquisition of the MP group.

Furthermore, this outcome measure is directly related to the outcome response time. As presented above the response time was longer in the MP group, which might have introduced a bias into the MP abilities outcome.

Last, Guillot and Collet (2005) reported that temporal equivalence between imaged and physically performed movements can be observed in highly automatic activities. But in non-automatic movements equivalence is frequently not observed. Factors which might be associated with a shorter mental duration were competitions and long preparation times. Both factors were present in this study.

One unexpected finding was related to the participant's self-reported confidence. It was expected that a higher self-confidence would be associated with a better performance. At least for athletic performance there seems to exist such an association (Feltz 1988). Here the group with the lower performance (i.e. nMP group) rated their confidence to perform the procedure higher than the MP group, which performed better on the performance measures. However, the finding was statistically not significant and the effect size was low. Therefore, it might not be justified to draw strong conclusions from this finding. Furthermore, similar findings were reported by Sanders et al. (2008), which evaluated that improvements in procedural skills were not related to student's self-confidence in their study about the effectiveness of MP on surgical skills.

It was identified that the MP group had one outlier with considerable lower performance evaluations on the APSPT 29 and the PSC. It was decided not to eliminate this participant from the analyses in order to fulfil the intention to treat requirements. Removing this participant from the analyses would have increased the effect size to a considerable amount in favour of the MP group.

6.4.1.2 Discussion of the feasibility

The feasibility information regarding possible adjustments for a larger follow up study. Most feasibility items showed that the application of the two motor learning principles was possible within this setting (i.e. physiotherapy education) and for this procedure (transfer procedure). The recruitment rate was very high (i.e. 97.5%). This might be explained by i) an interest to acquire a new physiotherapeutic procedure, ii) an interest in educational studies. Several participants decided to perform a study about procedural learning in physiotherapy education for their bachelor thesis after participation in this study and iii) a possible coercion might be assumed. This is further explored in the discussion of the general limitations below.

The failure rate was low at post-acquisition and retention testing. Indicating that the majority of participants in both groups might be ready to apply the procedure under supervision in clinical settings. However, two participants did not adequately perform the procedure. This failure rate was below the expected failure rate. A priori it was stated that at least 40% should fulfil this criterion.

The feasibility of the procedural skills training sessions showed that the participants were able to use MP as a training modality. It was expected that the participants would have some problems using this training principle. But during the session MP was performed as prescribed. When participants practiced physically for a prolonged time they were asked to continue with the MP but this occurred only once or twice. However, a procedural skills training using MP was not a standard intervention for this study population. It could be possible that an increased use of this technique might enhance the MP abilities of the group. As presented above, the MP abilities of both groups were similar. With an increased exposure to MP the students might use MP more naturally and increase their abilities to use this training modality.

Another aspect might have decreased the feasibility of the MP training. Within the LEArN trial a ratio of 1 practice trial to 1 mental rehearsal trial was instructed. This was based on the best practice recommendations for mental imaging published by Schuster et al. (2011). However, other authors recommend to gradually increase the amount of mental repetitions between physical practice trials. Initially the authors recommend to start with a ratio of 1 physical practice trial to 5 mental repetitions, which may be increased to a ratio of 10 mental to 1 physical practice repetitions with increasing proficiency (Malouin and Richards 2010). This might have increased the ability to independently use MP for skill acquisition.

Furthermore, in contrast to other studies (e.g. Sanders et al. 2004; Arora et al. 2010) no relaxation exercises were performed prior to the exercises, which might have further increased the feasibility (i.e. the participants would be more prepared to use the technique) and effectiveness of the MP intervention. This approach was not followed because of pragmatic reasons.

Malouin et al. (2013) report that the use of relaxation exercises may be associated with potential benefits such as increased concentration and attention, a more vivid mental imaging and an increased motor performance. Especially, the study of Arora et al. (2011) showed that MP was more effective than physical practice alone. This might be caused by their use of relaxation exercises prior to the MP. Therefore, adding relaxation exercises to the MP intervention might increase the effectiveness in future studies and the lack of relaxation exercises might be regarded as a limitation of the LEArN trial.

The MP interventions in this study were prepared and validated within a separate study. The approach was adapted from Arora and colleagues (2011). Other studies using MP in HPE frequently used a non-systematic approach or did not describe how the script was designed (see chapter 4). The validation process might have increased the feasibility and relevance of the MP script.

Feasibility criteria of the outcome assessment showed that the equipment worked reliably. No data were lost during the recording of the performance measures. The camera position was adequate to evaluate all performances. The aspect, which might be improved for a follow up study were the voice recordings. Two participants spoke very quietly and therefore the communication between participant and therapist was hard to follow. This might have caused a biased estimation of the performance of these two participants. However, communication was not the most critical parameter during the performance assessment, which reduces the size of the possible measurement error. In future studies, the quality of the audio recordings should be cautiously monitored and participants should be reminded to speak loud enough to ensure the comprehensibility of the recordings.

The evaluation of the video performances required more time than estimated in the protocol. Therefore, the estimated resources should be adapted.

Another limitation for a future study is the required sample size. The calculations for a possible follow up study indicated that a sample of at least 140 participants should be recruited. This calculation was based on the APSPT 29 effect size. In contrast, a considerable smaller sample would be required when the effect size of the PSC would be used for the power calculations. This would reduce the number to recruit to 66 participants. Therefore, from a pragmatic point of view it is suggested to change the primary outcome and use the PSC for the comparison of MP versus nMP.

Finally, the analysis of common mistakes identified elements, which can be used to improve the educational scripts. Avoiding these mistakes could potentially increase the performance in both groups and affect the majority of outcome measures. Furthermore, the pool of common mistakes might be used to show future students how they can improve their clinical practice.

6.4.2 Discussion comparison external focus versus internal focus of attention

6.4.2.1 Discussion of the effectiveness

The main finding of the effectiveness analysis was that the IFA group showed significantly higher performance scores on the APSPT 29 and PSC outcome measures at the post-acquisition test. This was associated with a moderate (APSPT 29) or a large effect size (PSC). This higher performance was also observed at the retention test but was not statistically significant. However, effect sizes remained at least on a moderate level in favour of the IFA group.

Analysis of the APSPT's sub-dimension procedure execution was also statistically significant. Furthermore, the effect size was higher than the APSPT's total score and presented evidence that these motor skill specific items might be more sensitive to an educational motor learning approach than other items such a decision-making or communication.

The results of the retention test indicated that learning in the IFA group tended to be better than the learning in the EFA group, however this statement is made with caution as the results were not statistically significant. These findings were unexpected because single primary studies present numerous evidence for the superiority of an EFA. The advantage of this motor learning principle was reported mainly in sport specific studies (Wulf et al. 2002). No studies have been found using this principle in HPE. Systematic reviews investigating the effectiveness of this motor learning principle are more cautious to conclude a general superiority of an EFA (Peh et al. 2011; Kakebeeke et al. 2013). In chapter 3 a meta-analysis was performed and supported that performance is better in a group using the EFA approach in most studies. However, meta-regression showed that the variable "task complexity" was an important predictor within this comparison. Tasks with a higher complexity tended to benefit less from an EFA. Furthermore, only very few studies training non-laboratory based procedures were identified. In the meta-analysis, the procedure with the highest task complexity was classified as 3D on Gentile's framework (2000).

Within LEArN, the transfer procedure was classified as 4D on Gentile's framework as it had considerable complexity.

The following parameters were used: i) in-motion regulatory conditions, ii) inter-trial variability, iii) the therapist was classified as performing an active body transport and iv) object manipulation. Together these parameters show that the transfer procedure represents a very complex procedure, which presents various challenges for skill acquisition. Applying the findings of the meta-regression to this study indicate that the better performance of the IFA group can be explained. The meta-regression predicted an equal performance between EFA and IFA for skills with a complexity level of 3D. Using the regression coefficient to predict the effectiveness of an IFA approach with the task complexity set to 4D would result in an effect size of 0.28 SMD's in favour of an IFA approach. However, the size of the effect in this study was higher than predicted. This might be due to the small sample size of this study (e.g. a small study bias might be assumed). On the other hand, one might argue that a ceiling effect is possible regarding Gentile's framework. Other not classified parameters might further increase the task complexity and could explain the high effect size in favour of the IFA group. Furthermore, Wulf and Shea (2002) presented evidence that effectiveness of motor learning principles can vary between simple and complex motor skills. While they did not present evidence for the FoA principle it seems plausible that this motor learning might also work differently in relation to the task complexity.

6.4.2.2 Discussion of the feasibility

The discussion on the feasibility of this comparison (EFA vs IFA) briefly presents novel points that have not already been discussed for the other comparison (MP vs nMP). First, immediately after the training no participant "failed to perform the procedure". This presents evidence that both motor learning principles were feasible regarding this criterion. But the failure rate increased in both groups at the retention test endpoint to 33.3% in the EFA group and 22.2% in the IFA group respectively. Both failure rates at the retention test remained below the 40% threshold. The relatively high failure rate in the EFA group might be associated with the high drop-out rate in this group. It was explored whether the failure rate was caused by group specific errors, but the reasons for the classification were similar between groups. The mistakes were: i) the participants did not start well. That is the patient was turned to the wrong side and it was not possible to control and support the weaker side during subsequent steps, ii) the movements of the patient were not adequately anticipated and iii) shoulder, hip or trunk were not adequately stabilised. No group specific mistakes were observed, which might raise questions regarding the feasibility of the instructions of one specific group.

One challenge was to provide the instruction of the procedure with the appropriate FoA. To ensure this the educator was trained over a period of several weeks. Recordings of the practice sessions showed that the wording of the instructions was appropriate. Furthermore, the instructions in the study were substantially longer than instructions used in other studies investigating the effect of different FoA. Frequently, studies instruct motor skills with a statement consisting of less than 100 words (e.g. Ille et al. 2013; Makaruk et al. 2013). The scripts used for this intervention consisted over several hundred words due to the number of components. Instructions for other procedures in HPE might be slightly shorter or longer depending on the procedure, but probably the word count would be closer to the transfer procedure than the conciseness for a sport-specific motor skills (e.g. dart throwing). Therefore, health professions educators are facing more challenges to use a FoA intervention compared to other professionals working in sport disciplines. First, the scripts must be transformed and reworded to assure a specific FoA, and then using the script requires considerable preparation for the educator in order to not use the other focus.

The results of the power calculation revealed that the required sample size (n = 60) for a future study can be significantly smaller than for the comparison of MP. This can be attributed to larger effect sizes. As with the comparison of MP, it could be shown that the required sample size would have to be considerably smaller if a PSC would be used as the primary outcome measure. This reduced the required sample size to 20 participants, with 10 participants allocated to each group. In this pilot study 18 participants were recruited for the comparison EFA versus IFA. Therefore, the actual sample size was close to the calculated sample size. This suggests that this study was not seriously underpowered for this comparison despite the relatively small sample size. But power calculations from pilot studies should only be used with caution (Thabane et al. 2010). Kraemer et al. (2006) argue that a limited sample size might introduce a bias and therefore possibly distort the power calculations. For this reason, the power calculations in this pilot study should be used cautiously.

The analysis of common mistakes showed that the participants in the EFA group had problems with the placement of their hands and body parts, which might have led to the lower performance scores. A reference to a specific body part of the therapist was avoided as much as possible during the design of the EFA scripts. This approach was adapted from Wulf et al. (2002). For example, the EFA group was instructed: "… the patient should perform a controlled forward bending". IFA group participants were instructed to "place their hands on the sternum to control the trunk". The focus on the movement in the EFA group might have reduced their ability to adequately place their hands. This was further supported by questions during the procedural skills training. Participants in the EFA group asked questions with an IFA (e.g. "where should I place my hands on the patient"). In order to stay with the study protocol the feedback was given with an EFA. This represents a challenge for further enquiry. The instructions for the procedural skills training were cautiously prepared, while some feedback questions were predicted it was not possible to anticipate all raised questions. The feedback on these not foreseen questions were therefore given spontaneously, which might have introduced a bias. Future studies could possibly address this by defining feedback statements as well. However, while this might increase the rigour it would take practice away from a real-life situation.

A further limitation of this study was that the duration of the procedural skills training was limited to 1.5 hours and was only performed once. This was chosen because of pragmatic reasons (i.e. that the amount of time that is available for procedural training of this procedure in the curriculum at the UAS Valais-Wallis).

Other authors investigating motor learning principles HPE used a similar approach to stay close to realistic practice schedules (Brydges et al. 2007). But compared to studies investigating the effect of sport related motor skills this represents a very small duration with few repetitions. For example, Southard and colleagues scheduled six practice sessions with a total amount of 90 trials to study the effect of a FoA on a throwing motor skill (Southard 2011). It cannot be excluded that the effect of the FoA would be different in situations with more practice trials.

6.4.3 General limitations - both comparisons

6.4.3.1 Sample size and power

One major limitation of this study was the small sample size. Findings of smaller studies are known to show different, sometimes higher effects than larger studies (Sterne et al. 2000). Several reasons have been proposed for a possible small study bias (Schwarzer et al. 2015): i) selective reporting of favourable outcomes, ii) selection bias (i.e. selection of a sample with specific variables, which predict a more favourable outcome), iii) publication bias and iv) coincidence (Rothstein et al. 2006). The presence of a small study bias cannot be ruled out, but several measures were taken to minimize the aforementioned bias risks. First, all anticipated outcome measures were specified in a protocol. The protocol was submitted to external review but was not published. Second, the selected study population represented a complete study cohort at the UAS Valais-Wallis. The selection criteria were not developed to select the participants in such a way that a positive result of the experimental treatment would have been expected. The eligibility criteria were relatively pragmatic set to increase the recruitment rate. However, as participants were only recruited from a single research centre it may be possible that students at this centre are different form students in other institutions. This might have been avoided by using a multi-centre approach, but this would have required considerably more resources, which were not available. Furthermore, the randomisation performed by an external person further reduced the risk of a selection bias. Last, a small study bias might have occurred because of coincidence. Considering the small sample size, outliers might distort the findings. For example, the drop-out rate in the EFA group at the retention test might be such a coincidence. If all these aspects are considered, then it can be argued that appropriate epidemiological methods were taken to reduce the risk of a potential small study bias in this study. Furthermore, the study was repeated with a different task procedure (i.e. vestibular rehabilitation) in a different study cohort.

6.4.3.2 Ethical risks and precautions

Since all participants of a cohort of students were invited and the primary investigator is a lecturer of the institution some students might have felt an obligation to participate. This cannot be excluded but several precautions were taken. For example, the study information was provided by an independent person and participants were informed that their performance would be rated by an external person not involved in teaching. A control group without an active comparator was not implanted in the study design to avoid a negative educational experience. The follow up rate of the retention test provided some indications that the precautions taken might have been sufficient to prevent possible coercion. Five of the original 36 participants did not perform the retention test. From an epidemiological point of view this is undesirable but from an ethical point of view this indicates that participants felt no obligation to complete all measures.

6.4.3.3 Handling of missing values

Within the protocol, a LOCF analysis was anticipated to impute missing values but this approach was not followed because of two reasons. First, for a LOCF analysis to be unbiased the data which is used for the imputation must have the same distribution as the unknown missing data (Lachin 2016). This was not the case for the data of the LEArN trial. For example, the median and IQR of the primary outcome “APSPT 29” changed considerably between the post-acquisition test and the retention test. Using the values of the post-acquisition test to replace missing values at the retention test would have probably introduced a relatively high bias in favour of the group with more missing values. Second, more general aspects regarding the LOCF validity were raised by Kenward and Molenberghs (2009). Furthermore, the European Medicines Agency (2010) recommended to use the LOCF method only in certain restrictive cases.

Using a LOCF might cause overly optimistic results. In studies investigating skill acquisition, findings of a retention test frequently show a lower performance than tests scheduled immediately after the practice session. For example, a systematic review which was used to prepare the LEArN trial found that data from many individual studies showed a deterioration within groups between the post-acquisition and the retention test (Sattelmayer et al. 2016a). Therefore, a decision was made to use MI to generate missing values. Multiple imputation is a statistical method and can be used to avoid the above-mentioned bias when applied appropriately (Sterne et al. 2009). Guidelines for imputation presented by White et al. (2011) and Buuren and Groothuis-Oudshoorn (2011) were followed. Among other measures, a sensitivity analysis was performed to investigate the effect of a departure from the assumption made in the primary analysis (i.e. the findings of the imputed data set were compared with an analysis of all randomised participants with complete observations). The sensitivity analysis showed for both comparisons that the direction of the effect did not change between the analyses. As expected the power of the analysis with the imputed values was higher compared to the analysis with the complete cases. Overall this indicated that the imputation process did not introduce a substantial bias into the data set. However, the findings of the retention test for the comparison EFA versus IFA should be interpreted cautiously because of the high rate of imputed to observed values within the EFA group.

Missing values were not imputed for the feasibility analysis. This was not done, since neither significance tests nor effect sizes have been calculated, which both benefit from higher power.

6.4.3.4 Other limitations

A major limitation of this study was that only limited evidence is available regarding the measurement properties of the APSPT 29. This measurement instrument was developed based on a systematic review of existing measurements in physiotherapy education (Sattelmayer et al. 2017). Then potentially relevant items and scoring criteria were discussed with relevant stakeholders (i.e. students and educators). Finally, the structural validity of the APSPT 29 was evaluated in a pilot study with the help of Rasch-analysis. Item fit statistics were used to identify items with misfit. Furthermore, the internal consistency of the APSPT was analysed with a Cronbach's alpha of 0.95.

Using the COSMIN framework (Mokkink et al. 2010) these points indicate that some limited evidence for the following measurement properties of the APSPT is available: internal consistency, content validity and structural validity. However, evidence for the following measurement properties was missing: reliability (test-retest, intra-rater and inter-rater), measurement error, criterion validity, construct validity and responsiveness. To partly, address these limitations the inter-rater reliability of APSPT 29 was analysed. A second independent rater was asked to score the video recordings of the retention test. An ICC (2,1) of 0.79 for the total score of the APSPT 29 was analysed indicating adequate inter-rater reliability. The COSMIN framework recommends a minimum value of 0.7 for reliability estimates.

The same limitations apply to the PSC, which was developed based on the content of the procedural skills. No evidence was available regarding measurement properties such as reliability, validity or responsiveness. In order to establish an indicator for the inter-rater reliability a second independent rater evaluated the video recordings of the retention test with the PSC. The analysis showed an ICC (2,1) of 0.92 for the total score of the PSC indicating adequate inter-rater reliability. However, these analyses were performed after the primary analyses of the LEArN trial, which is a considerable limitation.

The self-reported confidence in applying the transfer technique was measured with a modified questionnaire. Only three out of the proposed six items were used (Sanders et al. 2004). This limitation was inevitable because the remaining three items were designed to measure self-reported confidence in surgical procedures. While this may have introduced a bias into the measurement of self-reported confidence and certain aspects might have been missed, it still provides an indication of confidence. A further limitation was that the cut-off values for the feasibility analysis of the recruitment rate and failure rate were based on pragmatic reasoning and not on hard evidence because it was assumed that i) the recruitment rate might vary considerably based on the population and the location and ii) failure rates reported in other HPE disciplines using different procedures may not be relevant for this specific procedure.

6.4.4 Conclusion - acquisition of a transfer procedure

The analysis of task procedure 1 showed that it was possible to perform a study investigating the feasibility and effectiveness of two motor learning principles with the selected transfer procedure using physiotherapy students as participants. Findings of the comparison MP versus nMP indicated that MP may be useful in an educational setting. Findings regarding the effectiveness did not allow strong conclusions, and in the light of the non-significance of the analysis of the APSPT 29 at the post-acquisition (p: 0.2) and retention test (p: 0.45) it is not possible to state that MP has additional benefits on skill acquisition.

The use of MP was feasible and educators might consider using the motor learning principle to teach complex skills. However, this requires the careful development of valid MP scripts. The development of MP scripts for this study required considerable time and resources.

The results of the comparison EFA versus IFA on skill acquisition for the transfer task showed that the performance was better acquired when an IFA was used. This finding was novel and possible explanations were explored (i.e. possibly this was related to the high task complexity of the transfer procedure). To contrast this finding with the existing literature one might use the systematic review presented in chapter 3 as reference for data of related studies. Within the meta-analysis 7 studies were included comparing an EFA with an IFA on skill acquisition at post-acquisition testing. Two of the studies showed statistically significant findings in favour of an EFA

(Zachry et al. 2005; Zarghami et al. 2012). Four studies showed results in favour of an EFA but findings were not statistically significant (Southard 2011; Ille et al. 2013; Makaruk et al. 2013; Porter et al. 2015) and one study (Koedijker et al. 2007) was in favour of an IFA but findings were not statistically significant. Furthermore, the pooled overall effect was in favour of an EFA with a moderate effect size (SMD: -0.54; 95%CI between -0.86 and -0.22).

Given this large body of evidence in favour of an EFA the findings of this pilot study must be used with caution and it is recommended to investigate the effectiveness of an EFA versus IFA approach in this setting in future studies with a larger sample size and with a variety of complex tasks.

The use of a FoA in relation to skill acquisition in an educational setting is not without challenges. First, the complexity of the procedure requires to be classified and then the instructions should be modified to ensure the appropriate FoA. This requires sufficient resources and experience.

An unexpected finding was that the participant's self-confidence indicated a different group superiority for both comparisons (i.e. the students who performed better were less confident and vice versa). This might be caused by several reasons and warrants further inquiry. Both motor learning principles were subject to further exploration (i.e. task procedure 2) where the effectiveness and feasibility was investigated on the acquisition of a set of procedures in vestibular rehabilitation.

In summary, for the transfer task, at the end of acquisition the MP and the IFA performed better on measures of performance but these findings were not statistically significant. At the end of the retention period - these changes were reduced. Participants using nMP and EFA principles were more confident about their ability to use the technique.

6.5 Results - LEArN Trial - task procedure 2 - vestibular rehabilitation procedure

6.5.1 Study population - task procedure 2

A convenience sample of 42 students were invited to participate in the study of task procedure 2. Two students were excluded (Figure 6.1 on page 106). One could not participate due to medical reasons, the other student gave no reason. Therefore, a sample of 40 participants was recruited for the task procedure 2 of the LEArN trial (learning of vestibular rehabilitation procedures). Participants were randomly allocated as follows: group 2A “mental practice (MP)” (n = 10); group 2B “no mental practice (nMP)” (n = 9); group 2C “external focus of attention” (n = 9) and group 2D “internal focus of attention” (n = 12).

All included participants followed the procedural skills training intervention and completed the post-acquisition test immediately after the intervention. The retention test (three weeks after the intervention) was performed by 38 participants. Two participants (n=1 group 2C and n=1 in group 2D) were lost to follow-up, due to lack of time, at this endpoint. All participants lost at the follow-up endpoint agreed that their data from the post-acquisition test first endpoint could be used for the analyses. Missing values at the retention test were obtained by MI. Imputations were performed in each group separately in order to follow the intention to treat principle (Buuren and Groothuis-Oudshoorn 2011).

6.5.1.1 Participants - task procedure 2

Subject characteristics for participants are summarised in Table 6.11. Overall considerably more female and French speaking participants were included. Groups were similar regarding the primary language. However, considerably more male participants were allocated, randomly, to group 2D compared to the other groups. The overall age of participants was 23.9 (SD: 1.87) years, with a balance for age, between groups. Previous academic performance was similar between groups. In the Swiss system marks can range between 0 (lowest performance) and 6 (highest performance).

Table 6.11 Demographic and educational data of included participants - task procedure 2

Variable		Group 2A (n = 10)	Group 2B (n = 9)	Group 2C (n = 9)	Group 2D (n = 12)	Overall
Gender	female	8	8	8	7	31
	male	2	1	1	5	9
Primary language	Swiss French	7	6	8	9	30
	Swiss German	3	3	1	3	10
Age (years)	mean (SD)	23 (2.65)	22 (1.25)	22.3 (0.94)	24.1 (1.32)	23.9 (1.87)
	median (IQR)	22 (2.25)	22 (1)	22 (1)	24 (2.25)	23.5 (2)
Previous examination (range 0 - 6)	mean (SD)	4.93 (0.29)	4.96 (0.26)	5.01 (0.35)	4.9 (0.44)	4.95 (0.35)
	median (IQR)	4.88 (0.38)	4.875 (0.5)	5 (0.75)	5.1 (0.62)	5 (0.5)

6.5.1.2 Data distribution

All groups presented signs of a non-normal data distribution regarding skew and kurtosis. Density plots showed signs of multimodal data distributions of at least one group for each outcome measure (Appendix xii). Lastly, the Shapiro Wilk test was performed to check statistically for a normal distribution. Despite the indications for non-normality the Shapiro Wilk significance test did not present evidence for non-normality. However, an informed decision was made to use non-parametric statistics for the analysis of effectiveness.

6.5.2 Comparison mental practice versus no mental practice

Nineteen participants were randomised. Ten participants were allocated to the MP group (2A) and nine participants were allocated to the nMP group (2B). All participants completed the post-acquisition (T1) and the retention test (T2).

6.5.2.1 Analysis of effectiveness

Table 6.12 summarises the findings of this comparison.

Table 6.12 Effectiveness outcome data comparing MP (group 2A) against nMP (group 2B)

Outcome measure		Post-acquisition test (T1)			Retention test (T2)		
		Group 2A (n = 10) MP	Group 2B (n = 9) nMP	Significance and effect size	Group 2A (n = 10) MP	Group 2B (n = 9) nMP	Significance and effect size
APSPT 29 (0-116 points)	mean (SD)	70.1 (SD: 16.52)	63.78 (SD: 10.31)	W: 61, p: 0.21; r: - 0.29	64.4 (SD: 25.2)	65.55 (SD: 19.55)	W: 45.5, p > 0.99; r: 0
	median (IQR)	73.5 (IQR: 21.75)	66 (IQR: 15)		62.5 (IQR: 41)	57 (IQR: 29)	
APSPT Subdimension PE (0-28 points)	mean (SD)	18.1 (SD: 4.97)	15.44 (SD: 3.68)	W: 64, p: 0.13 (*0.21); r: - 0.35	14.1 (SD: 7.21)	14.67 (SD: 6.41)	W: 45, p: > 0.99 (*0.99); r: 0
	median (IQR)	19.5 (IQR: 4.25)	15 (IQR:6)		13 (IQR:11.75)	12 (IQR: 12)	
PSC (0-26 points)	mean (SD)	19.9 (SD: 2.72)	19 (SD: 2.12)	W: 57, p: 0.34 (*0.43); r: - 0.22	17.9 (SD: 6.12)	17.44 (SD: 6.09)	W: 46.5, p: 0.93 (*0.99); r: - 0.01
	median (IQR)	21 (IQR: 4.5)	19 (IQR: 3)		19.5 (IQR: 8)	20 (IQR: 9)	
Response time (seconds)	mean (SD)	199.8 (SD: 75.58)	150.89 (SD: 37.85)	W: 64, p: 0.13 (*0.21); r: - 0.34	263.9 (SD: 65.48)	216.22 (SD: 67.96)	W: 67, p: 0.08 (*0.23); r: - 0.39
	median (IQR)	182.5 (IQR: 68.75)	157 (IQR: 45)		256 (IQR: 71)	197 (IQR: 88)	
Mental practice abilities (seconds)	mean (SD)	110.2 (SD: 84.78)	76.56 (SD: 42.03)	W: 54, p: 0.5 (*0.5); r: - 0.16	162.6 (SD: 55.07)	123.33 (SD: 69.54)	W: 66.5, p: 0.09 (*0.23); r: - 0.39
	median (IQR)	96.5 (IQR: 121.75)	80 (IQR: 41)		156.5 (IQR: 60.5)	105 (IQR: 33)	
Self-reported confidence (0-12 points)	mean (SD)	8 (SD: 2.11)	5.89 (SD: 2.03)	W: 69, p: 0.049 (*0.21); r: - 0.45	7.8 (SD: 2.15)	7.33 (SD: 2.74)	W: 48.5, p: 0.8 (*0.99); r: - 0.06
	median (IQR)	8.5 (IQR: 3.75)	5 (IQR: 3)		8 (IQR: 1.75)	8 (IQR: 2)	

Key. MP: mental practice; nMP: no mental practice; p: p-value, *p-value corrected for multiple testing; PE: procedure execution; PSC: Procedure specific checklist; r: effect size; W: Wilkinson rank-sum statistic

6.5.2.1.1 Assessment of procedural skills (APSPT 29)

At post-acquisition testing (T1) the MP group had a higher median score of 73.5 versus 66 for the nMP group (Figure 6.13). This difference was not statistically significant. The effect size of r: - 0.29 indicated a moderate effect size in favour of the MP group. At the retention test (T2), MP had a slightly higher median score than nMP (62.5 versus 57 points). The difference was not statistically significant.

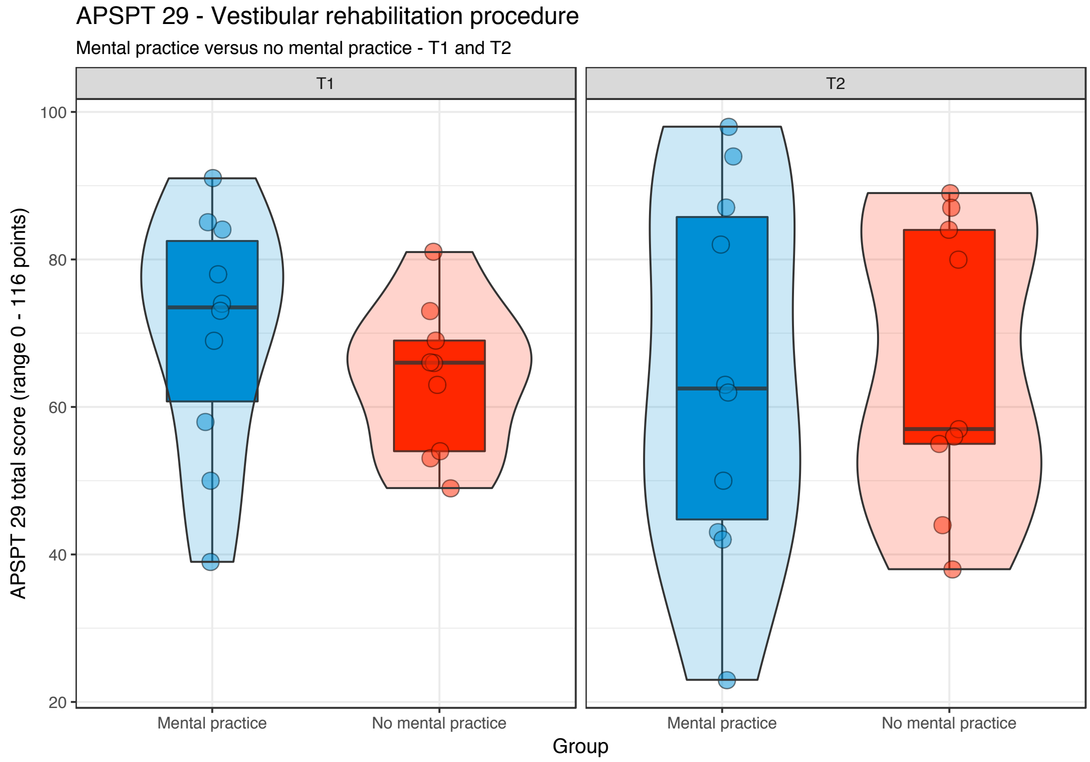


Figure 6.13 APSPT 29 - comparison MP (2A) versus nMP (2B). T1: post-acquisition test; T2: retention test

6.5.2.1.2 APSPT Sub-dimension procedure execution

At post-acquisition testing the median score was higher in the MP group compared to the nMP group (19.5 versus 15 points) on the APSPT sup-dimension “procedure execution” (Figure 6.14). The effect size for this between group difference was moderate (r: - 0.35) and did not reach statistical significance. One outlier was identified in the MP group at T1.

The performance at the retention test was similar between groups. MP had only a minimal higher median score compared to nMP (mdn: 13 versus 12 points). The findings were not statistically significant. Both groups showed at T2 signs of a bimodal data distribution.

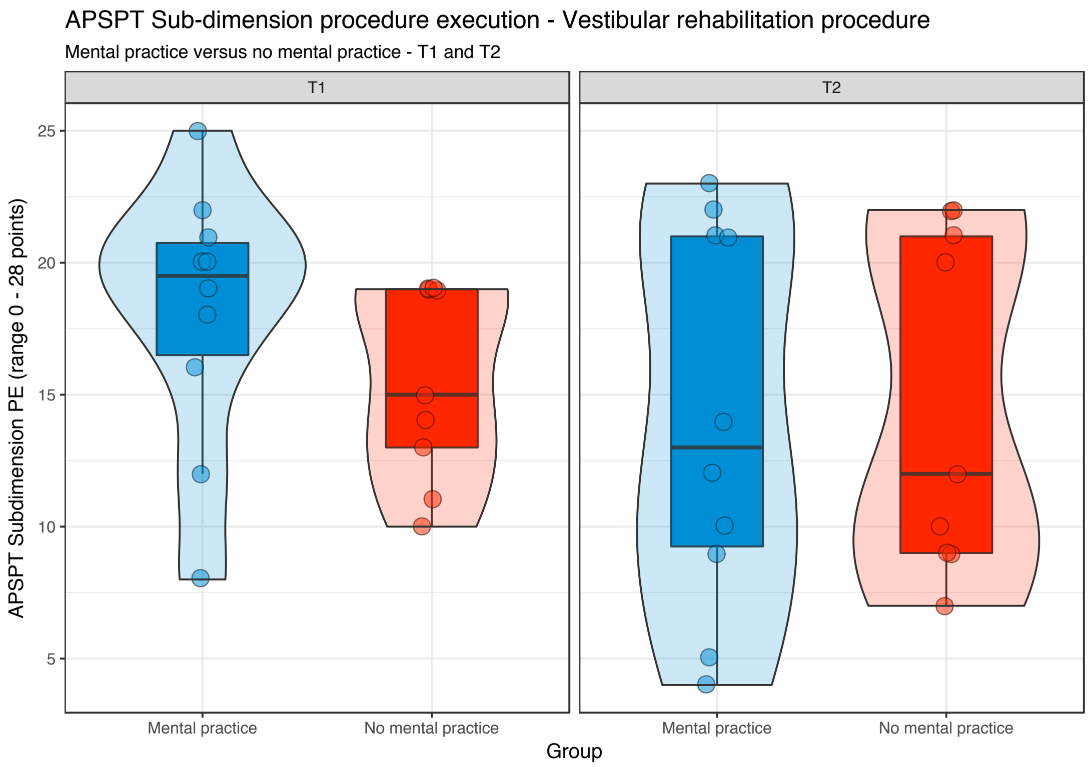


Figure 6.14 APSPT Sub-dimension procedure execution - comparison MP (2A) versus nMP (2B). T1: post-acquisition test; T2: retention test

6.5.2.1.3 Procedure specific aspects

The median performance measured with a PSC at the post-acquisition test was higher in the MP group (mdn: 21 points) compared to the nMP group (mdn: 19 points) (Figure 6.15). A small to moderate effect size of r: - 0.22 was analysed in favour of the MP group. Findings were statistically not significant.
The point estimates at the retention test were similar between groups and the between group difference was not statistically. A broad spectrum of performances was observed in both groups but no outliers were identified.

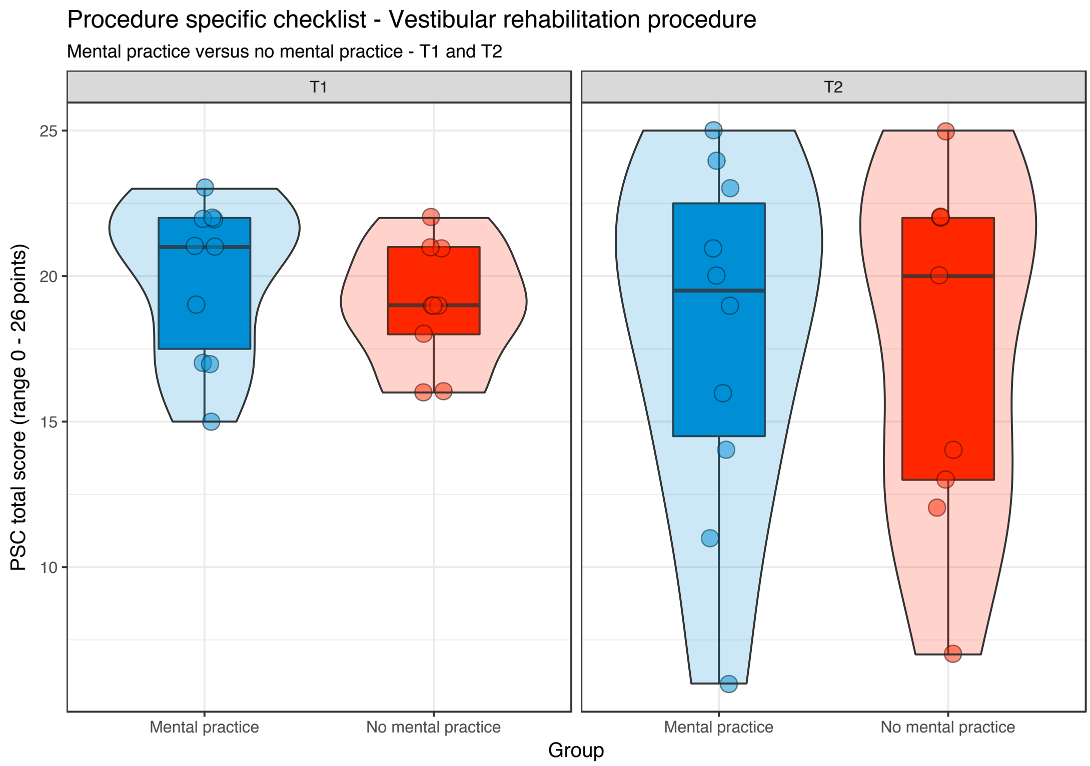


Figure 6.15 PSC - comparison MP (2A) versus nMP (2B). T1: post-acquisition test; T2: retention test

6.5.2.1.4 Response time

The median response time (i.e. the duration of the procedure) was longer in the MP group mdn: 182.5 seconds compared to mdn 157 seconds in the nMP group at the post-acquisition test (Figure 6.16). The effect size for this outcome measure was moderate (r: - 0.34) but was not statistically significant.

This finding did not change at the retention test. The median duration was 256 seconds in the MP group versus 197 seconds for nMP. The effect size for this between group difference was moderate to large (r: - 0.4) but the finding was not statistically significant.

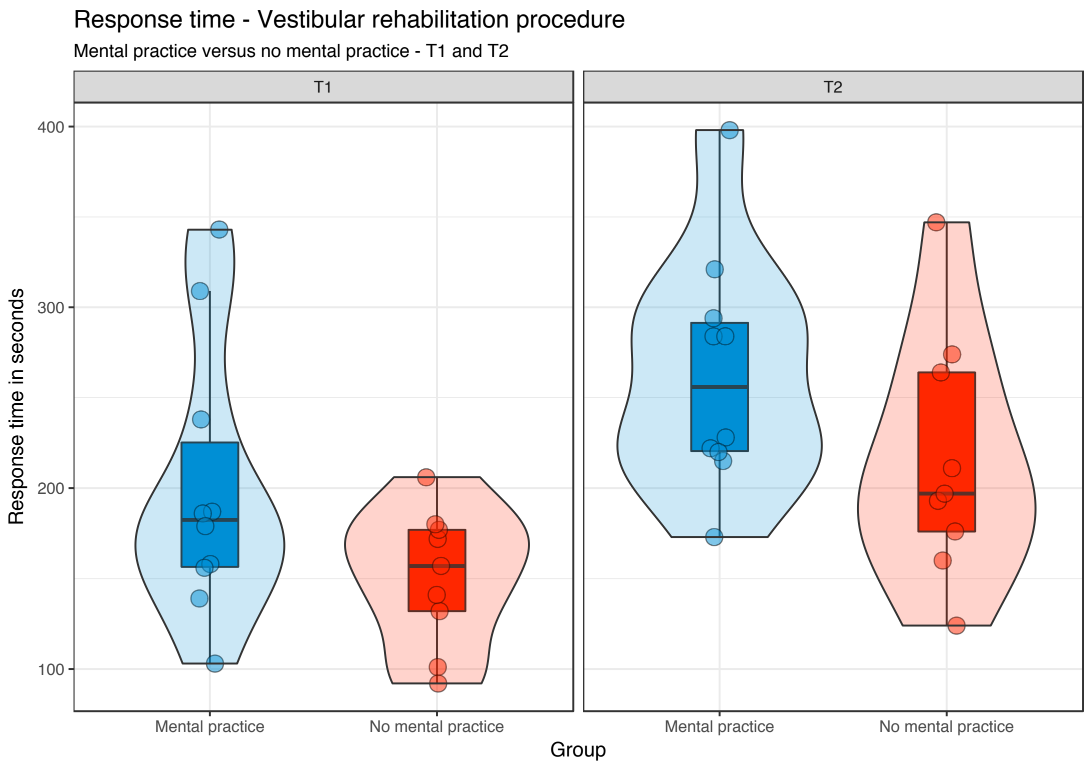


Figure 6.16 Response time - comparison MP (2A) versus nMP (2B). T1: post-acquisition test; T2: retention test

6.5.2.1.5 Mental practice abilities

The MP abilities measured with a mental chronometry approach (i.e. the difference between physical and mental response time was calculated) were higher in the nMP group at the post-acquisition endpoint (Figure 6.17). The difference between the physical response time and the mental response time in the MP group had a median of 96.5 seconds versus 80 seconds for nMP. The effect size for this finding was small (r: - 0.16) and did not reach the level of significance.

This trend increased at the retention test, where a median of 156.5 seconds was analysed for MP compared to 105 seconds for the nMP group. This represented a moderate effect size (r: - 0.39). The between group difference was not significant. Two outliers were identified in the nMP group at the retention test.

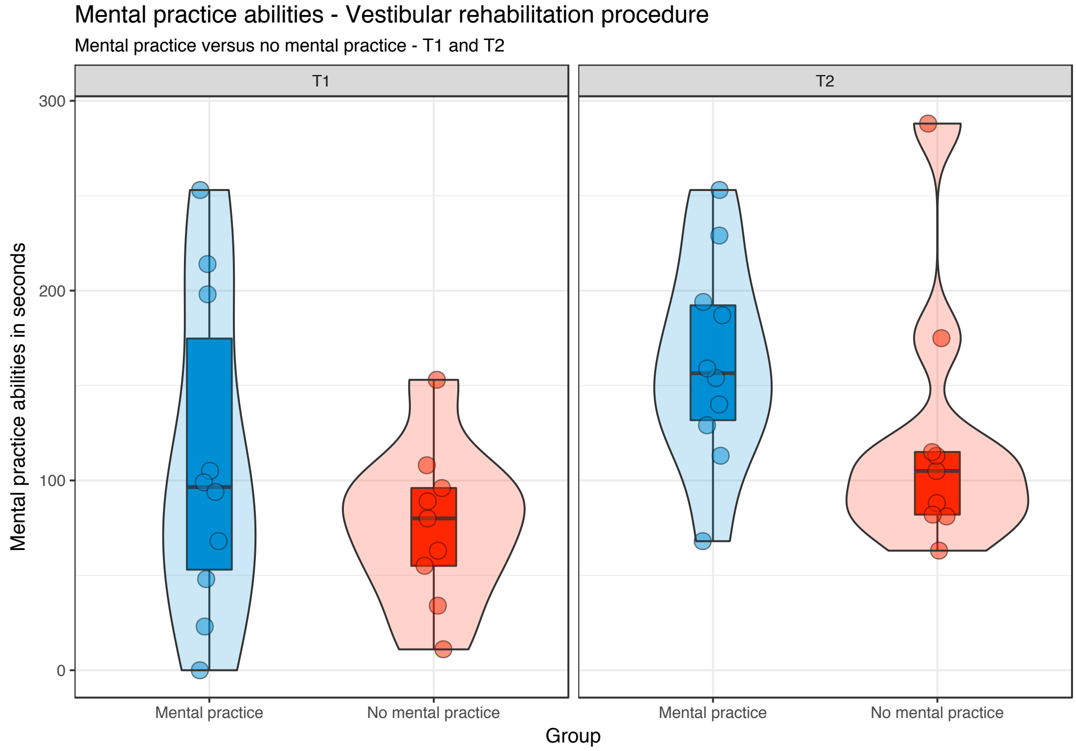


Figure 6.17 Mental practice abilities - comparison MP (2A) versus nMP (2B). T1: post-acquisition test; T2: retention test

6.5.2.1.6 Self-reported confidence

The self-reported confidence in the MP group was higher (mdn: 8.5 points) compared to 5 points for nMP at the post-acquisition test (Figure 6.18). The effect size of this between group difference was moderate to large (r: - 0.45) and statistically significant (p: 0.049). However, after correction for multiple testing the p-value increased to 0.21 and the findings were above the significance level. At the retention test both groups had a similar self-reported confidence (mdn: 8 points).

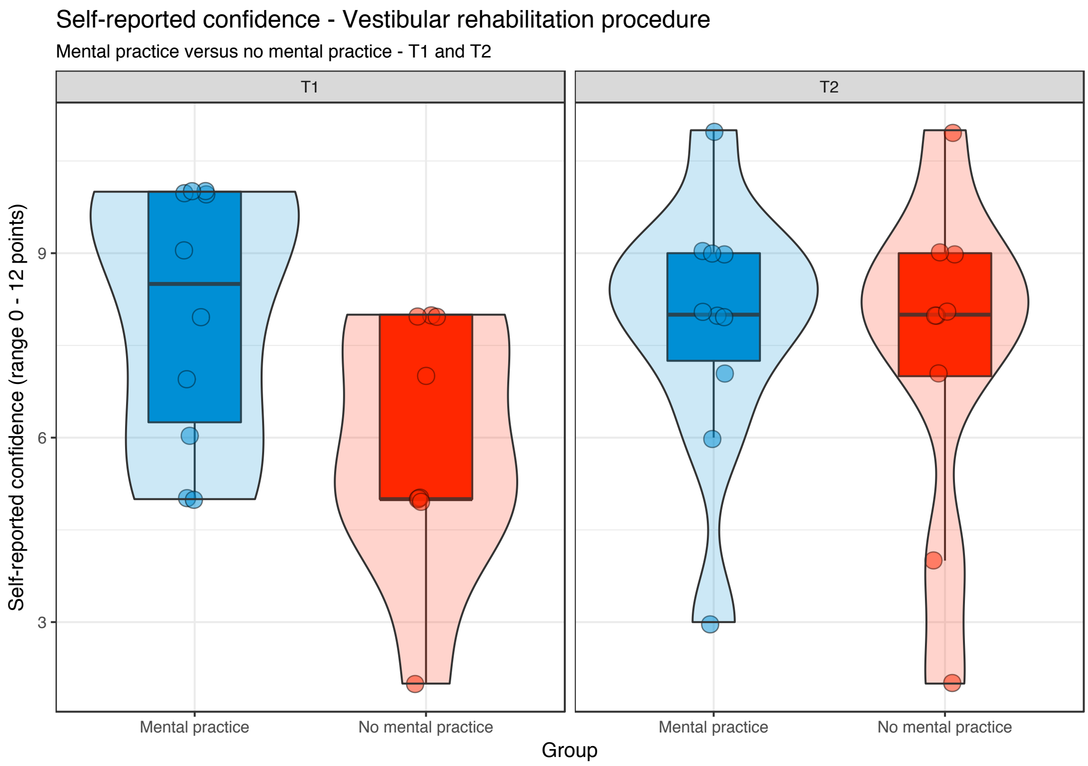


Figure 6.18 Self-reported confidence - comparison MP (2A) versus nMP (2B). T1: post-acquisition test; T2: retention test

6.5.2.2 Analysis of the feasibility

Within this section data related to the feasibility of the comparison MP against nMP is presented.

6.5.2.2.1 Recruitment rate

Forty-two people were approached for this study, with a total of 40 being recruited. This resulted in a recruitment rate of 95.2 %.

6.5.2.2.2 Failure rate

Testing of participants, post-acquisition, showed only one MP participant classified as "failed to perform". This equates to a 10% failure rate in the MP group. This was considerably below the predefined threshold of 40%. In the nMP group all participants adequately performed the procedure post-acquisition (Table 6.13). At the retention test the number of participants "failing to perform" increased in both groups. This resulted in failure rates of 30% (3/10) in MP and 37.5% (3/8) in the nMP group.

Table 6.13 Failure rate - comparison MP (2A) versus nMP (2B).

T1	Group 2A (MP)	Group 2B (nMP)	T2	Group 2A (MP)	Group 2B (nMP)
Failed to perform	1	0	Failed to perform	3	3
Performed procedure	9	8	Performed procedure	7	5

NB. T1: post-acquisition test; T2: retention test

6.5.2.2.3 Feasibility of the procedural skills training session

First, the time needed for the instructions was similar in both groups (i.e. 29 min for the MP versus 31 minutes in the nMP group). The participants needed between 30 and 50 minutes to practice the procedures. That is the first pair of participants indicated after 30 minutes that they felt sufficiently proficient. The use of the MP provided some challenges as it was unfamiliar for participants. If the participants had questions regarding the MP these were answered. Despite the novel situation all participants performed the MP. Challenges regarding the instruction of the procedure did not occur.

One participant in the MP group reported that 10 minutes more practice time should be provided. This was in contrast to the observation that all participants terminated their practice before the official end of the training session.

Most reported challenges in the MP group were related to i) MP was a novel kind of practice, ii) the large number of procedural steps caused recall problems and iii) three participants mentioned MP was difficult because of a noisy environment. A further challenge was the visualisation of the vestibular system. Most challenges in the nMP group were related to the placement of the hands during the execution of the procedures. Challenges were also reported related to memorisation -, reasoning processes and patient safety. All identified challenges and problems are presented in Table 6.14.

Table 6.14 Identified challenges and problems - comparison MP versus (2A) versus nMP (2B)

Challenges & problems	Group 2A (MP)	Group 2B (nMP)
Communication	n.a.	1
Concentration	3	n.a.
Hand placement	n.a.	3
Memory	2	2
MP training	4	n.a.
Preparation	n.a.	1
Reasoning	1	2
Security	n.a.	2
Video assessment	1	n.a.
Visualisation vestibular system	2	2

6.5.2.2.4 Feasibility of the outcome assessment

First, more time than anticipated was used to evaluate the video recording. Evaluation of the performance and documenting the results in the case report forms required on average 20 minutes. This resulted in a workload of 26 hours for the video evaluations. During the assessment of the video recording of the post-acquisition test, the assessors mentioned that the camera position should be optimised. Therefore, the camera position was modified for the retention test. Despite the positioning issues, it was possible to evaluate all recordings. Use of both assessment forms (APSPT 29 and PSC) was possible but it was reported that the performance could be evaluated faster with the checklist.

6.5.2.2.5 Sample size

The effect sizes for the outcomes "procedural performance" measured with the APSPT 29 and the "procedural specific aspects" measured with the PSC were used to calculate the sample size of a larger follow-up study (Faul et al. 2007).

A medium effect size of r: - 0.29 was analysed in favour of the MP group at the post-acquisition test. For the power calculation, a two-tailed test with the error probability α of 0.05 and the power of 0.95 was set. These parameters predicted that a total sample size of 150 participants (i.e. 75 in each group) would be required in a future study.

The effect size in favour of the MP group measured with a PSC was r: - 0.21. Using this effect size to estimate the required sample would increase the total size of the sample to 312 participants, with 156 participants allocated to each study arm.

6.5.2.3 Miscellaneous aspects

Two miscellaneous feasibility aspects are presented below. Common mistakes during the performance of the procedures and the follow-up rate.

Analysis of common mistakes showed that the procedure steps which do not require specific motor skills received the lowest performance ratings. In both groups, the procedure preparation steps (i.e. for the assessment and treatment) scored relatively low. For example, insufficient information was provided. Most of the errors in the assessment with the Dix Hall-pike test were caused because only one side of the patient was tested. In both groups only two participants tested both sides. With regard to the interventional procedure the procedure step with the lowest performance was providing of post procedure instructions.

Regarding movement related procedure steps, the MP group showed mistakes during the fourth step of the Canalith Repositioning Technique (CRT). There the patient's head was not adequately supported. Common problems in the nMP group occurred during the third step of the CRT manoeuvre. Some participants did not adequately hold the patient's head in cervical extension. When the liberatory manoeuvre was used the participants in the nMP group had difficulties performing and controlling a specific movement with the patient's head in step 4.

All participants in both groups completed the post-acquisition test and the retention test. Therefore, risk of bias resulting from loss to follow-up was small for this comparison.

6.5.3 Comparison external focus versus internal focus of attention

Twenty-one participants were randomised. Nine participants were allocated to the EFA group and 12 participants were allocated to IFA. In both groups one participant was lost to follow-up at the retention test.

6.5.3.1 Analysis of effectiveness

The results on the effectiveness of the two interventions with five outcome measures are presented in tabular form (Table 6.15) and then discussed in detail.

Table 6.15 Effectiveness outcome data comparing EFA (group 2C) versus IFA (group 2D)

Outcome measure		Post-acquisition test (T1)			Retention test (T2)		
		Group 2C (n = 9) External focus of attention	Group 2D (n = 12) Internal focus of attention	Significance and effect size	Group 2C (n = 9) External focus of attention	Group 2D (n = 12) Internal focus of attention	Significance and effect size
APSPT 29 (0-116 points)	mean (SD)	63.88 (SD: 16.45)	65.58 (SD: 15.79)	W: 53, p: 0.97; r: - 0.01	70.67 (SD: 21.81)	73.08 (SD: 20.85)	W: 51.5, p: 0.88; r: - 0.03
	median (IQR)	64 (IQR: 18)	65 (IQR: 30.75)		81 (IQR: 26)	78.5 (IQR: 36)	
APSPT Subdimension PE (0-28 points)	mean (SD)	17.67 (SD: 4.18)	17.25 (SD: 4.33)	W: 55.5, p: 0.94 (*0.94); r: - 0.02	16.78 (SD: 6.7)	17.33 (SD: 6.37)	W: 49.5, p: 0.78 (*0.78); r: - 0.06
	median (IQR)	18 (IQR: 5)	19 (IQR: 7.25)		20 (IQR: 11)	19.5 (IQR: 10)	
PSC (0-26 points)	mean (SD)	19.33 (SD: 2.96)	20.58 (SD: 3.02)	W: 41, p: 0.37 (*0.74); r: - 0.2	16.89 (SD: 6.41)	20.58 (SD: 4.96)	W: 32, p: 0.13 (*0.26); r: - 0.33
	median (IQR)	19 (IQR: 3)	21 (IQR: 5)		18 (IQR: 7)	22.5 (IQR: 7.25)	
Response time (seconds)	mean (SD)	142 (SD: 38.61)	163.58 (SD: 74.22)	W: 52.5, p: 0.94 (*0.94); r: - 0.02	166.11 (SD: 36.86)	200.42 (SD: 54.92)	W: 31, p: 0.11 (*0.26); r: - 0.35
	median (IQR)	143 (IQR: 43)	133.5 (IQR: 111.25)		168 (IQR: 59)	199.5 (IQR: 31)	
Self-reported confidence (0-12 points)	mean (SD)	6.78 (SD: 1.56)	8.5 (SD: 0.8)	W: 19, p: 0.01 (*0.04); r: - 0.56	6.11 (SD: 2.76)	7.42 (SD: 2.94)	W: 38.5, p: 0.28 (*0.37); r: - 0.23
	median (IQR)	6 (IQR: 2)	8.5 (IQR: 1)		5 (IQR: 3)	7.5 (IQR: 4.25)	

Key. P: p-value, *p-value corrected for multiple testing; PE: procedure execution; PSC: Procedure specific checklist; r: effect size; W: Wilkinson rank-sum statistic

6.5.3.1.1 Assessment of procedural skills (APSPT 29)

The EFA and the IFA group performed similarly (EFA: mdn: 64 and IFA: mdn: 65 points) at the post-acquisition endpoint (Figure 6.19). The difference between groups was statistically not significant. Data in the IFA group indicated a bimodal distribution.

At the retention test the EFA group had a slightly higher median performance (mdn: 81 points) than the IFA group (mdn: 78.5 points) but the difference was not statistically significant (p: 0.88).

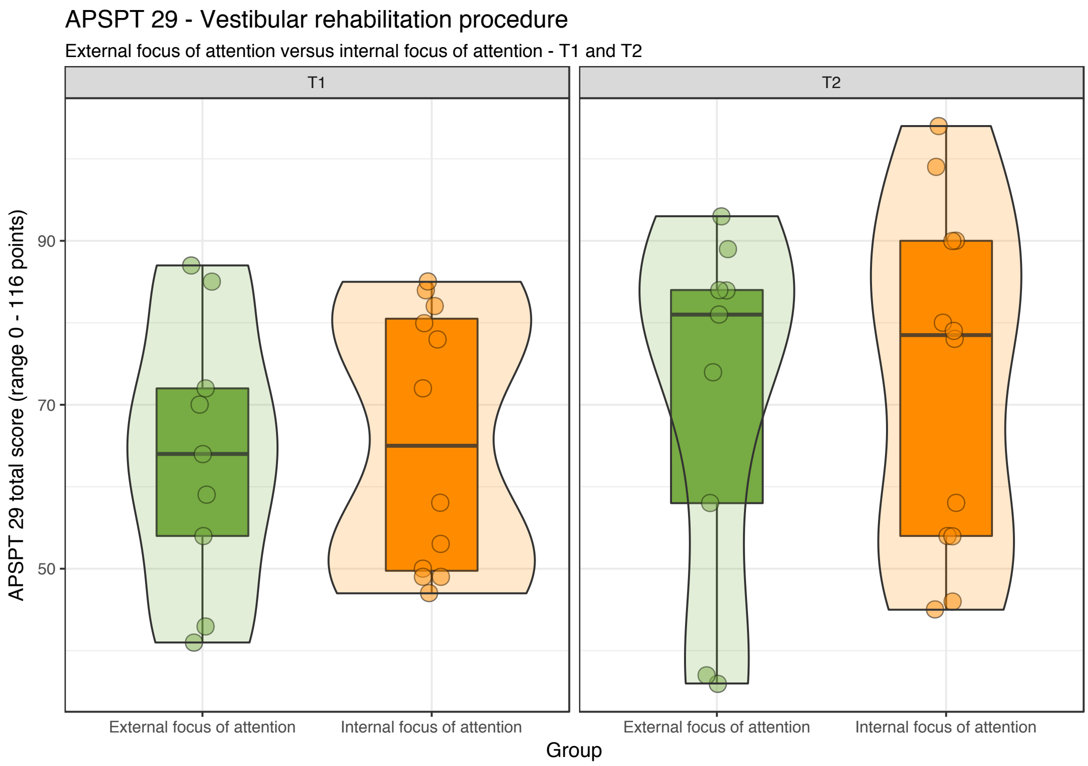


Figure 6.19 APSPT 29 – comparison EFA (2C) versus IFA (2D). T1: post-acquisition test; T2: retention test

6.5.3.1.2 APSPT Sub-dimension procedure execution

The observed median "procedure execution" was slightly higher in the IFA group mdn: 19 points versus 18 points in the EFA group at the post-acquisition endpoint (Figure 6.20). This difference was not statistically significant. At retention test the EFA group scored slightly higher on this outcome measure with a median of 20 points compared to 19 points in the IFA group. This finding was statistically not significant and an effect size of r: - 0.06 was analysed. A bimodal data distribution was found in the IFA group at both endpoints.

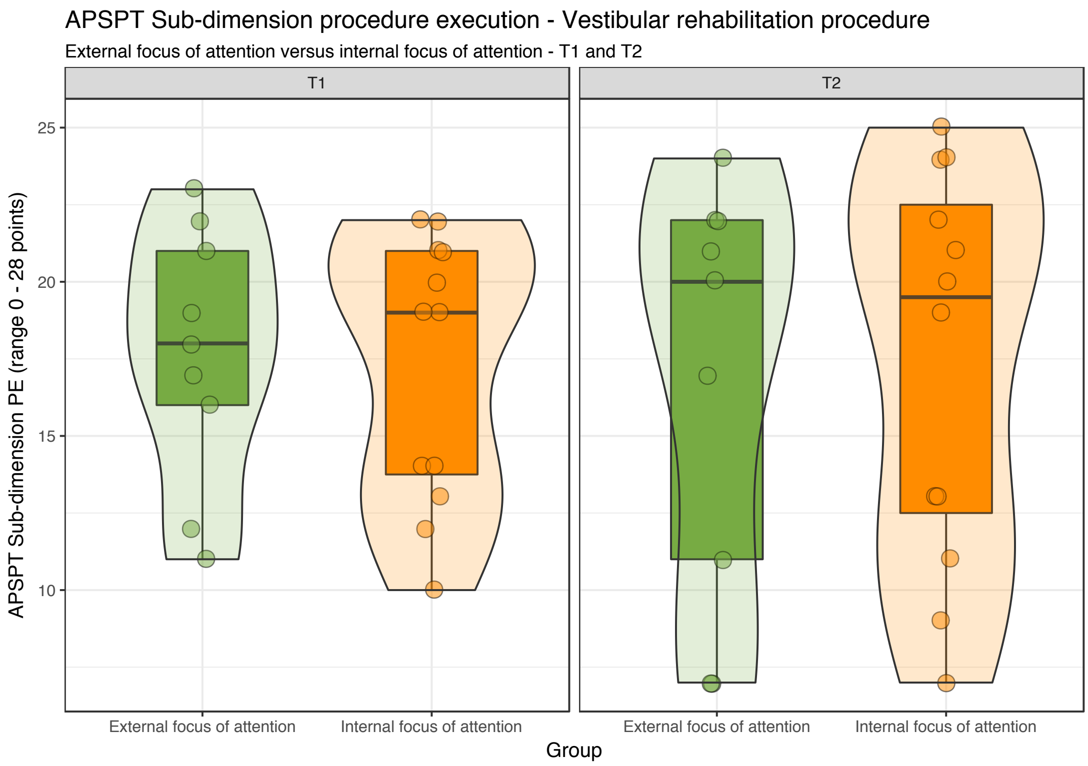


Figure 6.20 APSPT sub-dimension procedure execution – comparison EFA (2C) versus IFA (2D). T1: post-acquisition test; T2: retention test

6.5.3.1.3 Procedure specific aspects

The IFA group demonstrated a higher median performance measured with a PSC mdn: 21 points versus 19 points for the EFA group. A small to moderate effect size was analysed in favour of the IFA group (r: - 0.2) but the between group difference was not statically significant.

A slight decrease in performance was observed in the EFA group (mdn: 18 points) at the retention test (Figure 6.21). The IFA group showed an increased performance (mdn: 22.5 points). The between group difference was statistically not significant. A medium effect size (r: - 0.33) in favour of the IFA group was analysed for this between group difference.

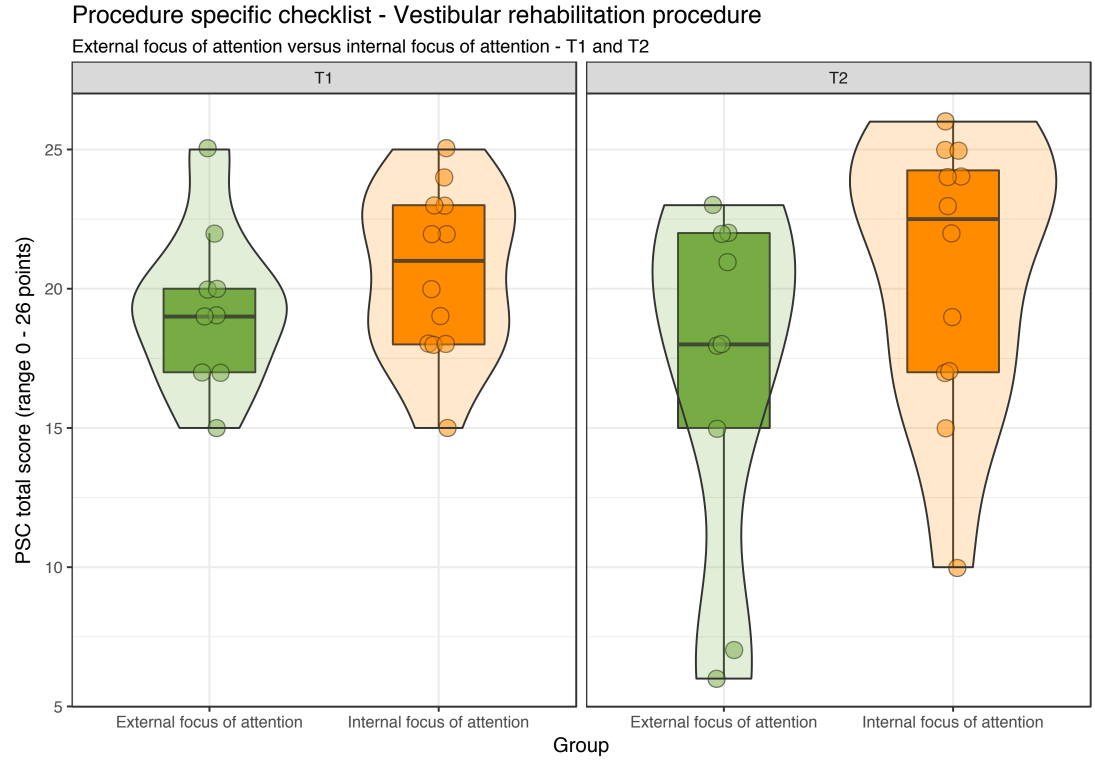


Figure 6.21 PSC comparison EFA (2C) versus IFA (2D). T1: post-acquisition test; T2: retention test

6.5.3.1.4 Response time

The IFA group needed less time to perform the procedure (mdn: 133.5 seconds versus 143 seconds for the EFA group). This difference was not statistically significant. Both groups showed an increased response time at the retention test (Figure 6.22). The EFA group needed a median time of 168 seconds to perform the procedure. The response time in the IFA group was considerable longer (mdn: 199.5 seconds). A moderate effect size was analysed for this difference (r: - 0.35) but it did not reach statistical significance. Three outliers were observed in the IFA group at T2.

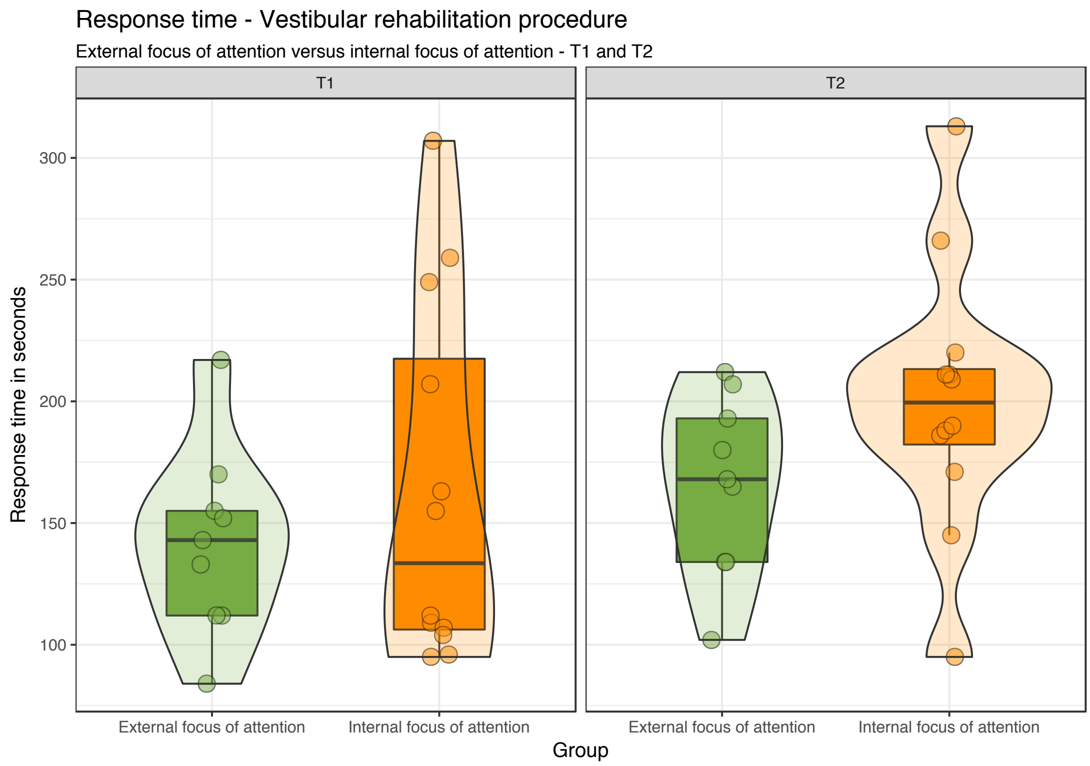


Figure 6.22 Response time - comparison EFA (2C) versus IFA (2D). T1: post-acquisition test; T2: retention test

6.5.3.1.5 Self-reported confidence

The median self-reported confidence was higher in the IFA group at the post-acquisition test (mdn: 8.5 points) compared to 6 points in the EFA group (Figure 6.23). This difference was statically significant (p: 0.04) and a large effect size of r: -0.56 was analysed in favour of an IFA.

At the retention test the self-reported confidence in both groups decreased (mdn: 5 for an EFA versus 7.5 points for an IFA). The between group difference had a small to moderate effect size of r: - 0.23 but was not statistically significant.

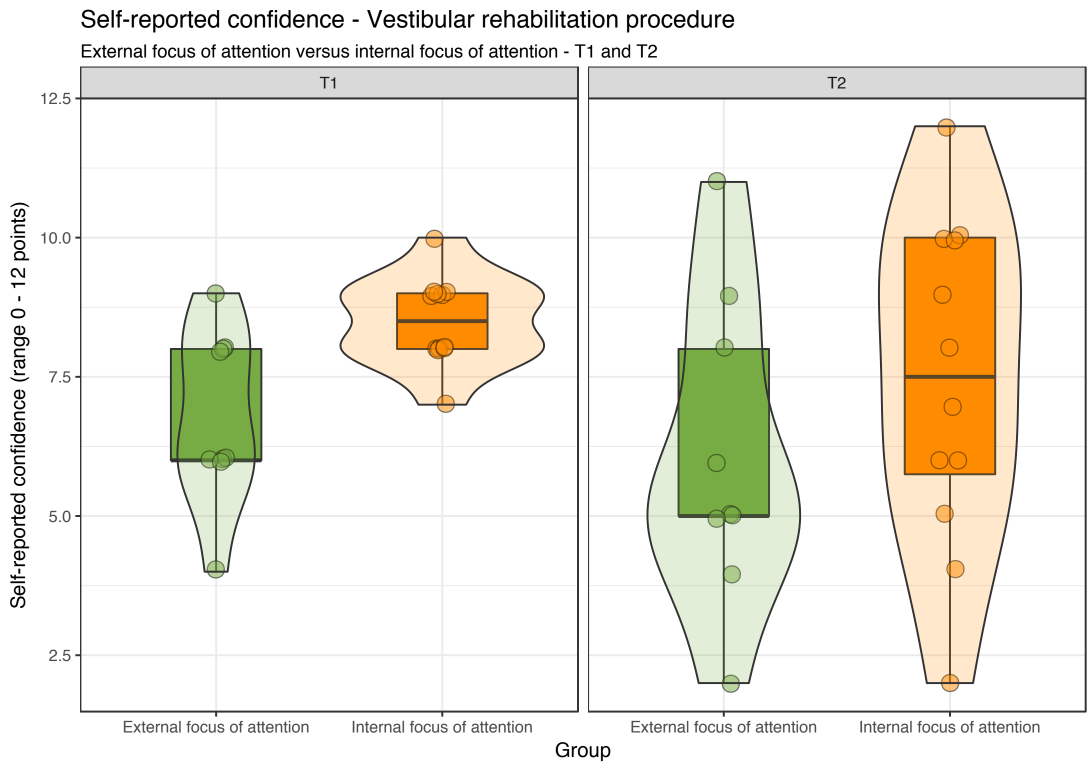


Figure 6.23 Self-reported confidence - comparison EFA (2C) versus IFA (2D). T1: post-acquisition test; T2: retention test

6.5.3.2 Analysis of the feasibility

Below the feasibility criteria are evaluated for the comparison EFA versus IFA group. Two of the feasibility criteria relate to the complete study of task procedure 2 - vestibular rehabilitation. These are the recruitment rate and the feasibility of the outcome assessment. Both have already been presented in section 6.5.2.2 and are not repeated within this section.

6.5.3.2.1 Failure rate

Testing of participants, post-acquisition showed only one EFA participant classified as "failed to perform". This equates to a 11.1% failure rate in the EFA group. In the IFA group, all participants adequately performed the procedure post-acquisition (Table 6.16). At the retention test the number of participants "failing to perform" increased in both groups. This resulted in failure rates of 25% (2/8) in EFA and 18.2% (2/11) in the IFA group.

Table 6.16 Failure rate - comparison EFA (2C) versus IFA (2D)

T1	Group 2C (EFA)	Group 2D (IFA)	T2	Group 2C (EFA)	Group 2D (IFA)
Failed to perform	1	0	Failed to perform	2	2
Performed procedure	8	12	Performed procedure	6	9

NB. T1: post-acquisition test; T2: retention test

6.5.3.2.2 Feasibility of the procedural skills training session

The time needed to instruct the procedures was different in both groups. Instructions in the EFA group had a duration of 32 minutes versus 40 minutes for the IFA group (caused by questions raised during the instruction session). The practice time was comparable in both groups. Participants practiced for at least 40 minutes. The main challenge for the educator was to ensure adequate wording of the instructions. The development of the training scripts required a duration of several weeks. During the training sessions, no mistakes with regard to an inappropriately used FoA were identified. This was also valid for the provided feedback.

All participants in the EFA group reported that enough time was available for the practice of the procedures. In contrast two participants in the IFA group mentioned that additional practice time would be needed (between 10 and 15 minutes).

The greatest challenge in both groups was the visualisation of the vestibular system during the different parts of the manoeuvres (i.e. three participants in the EFA versus nine in the IFA group). In addition, both group mentioned some difficulties related to reasoning processes (e.g. which interventional manoeuvre should be used when the test for the posterior semi-circular canal of the left side is positive). Furthermore, the EFA group mentioned challenges related to the hand placement and the IFA group mentioned problems with memorisation. All identified problems and challenges are presented in Table 6.17.

Table 6.17 Identified challenges and problems - comparison EFA (2C) versus IFA (2D)

Challenges & problems	Group 2C (EFA)	Group 2D (IFA)
Body position	1	3
Communication	1	n.a.
Hand placement	2	1
Memory	1	3
Reasoning	2	3
Security	n.a.	1
Specific procedure parts	n.a.	1
Visualisation vestibular system	3	9

6.5.3.2.3 Sample size

The between group difference on the primary outcome measure for effectiveness (APSPT 29) was very small. An effect size of r: - 0.01 was analysed in favour of the IFA group at the post-acquisition endpoint. To calculate the sample size for a follow-up study, a two-tailed test with the error probability α of 0.05 and the power of 0.95 was set. This resulted in a total sample size of 136,084 participants, with 68,042 participants allocated to each group. The between group difference on the PSC was considerable greater. There an effect size of r: - 0.2 was analysed in favour of the IFA group. Using this effect size for a power calculation reduced the required sample size to 326 participants, with 163 participants allocated to each group.

6.5.3.2.4 Miscellaneous aspects

Two miscellaneous aspects are presented below. Common mistakes which occurred during the performance of the procedure and the follow-up rate.

Common mistakes in the EFA group occurred during step five of the Dix-Hallpike manoeuvre. Only one participant performed the test on both sides. Regarding the intervention only one participant provided post-procedure instructions. Some minor mistakes occurred during the first step of the Dix-Hallpike test. There participants did not instruct and guide the patient into the correct starting position. With regard to the liberatory manoeuvre some problems occurred during step 4 (i.e. control a movement with the patient's head). Common mistakes in the IFA group were similar. Frequently, patients were not adequately instructed and informed about the procedure. Four participants did not perform the assessment on both sides and post-procedure instructions were omitted frequently. The motor skill, which caused most problems was the same as in the EFA group (i.e. step 4 of the liberatory manoeuvre). One participant was lost in each group at the retention test. Therefore, eight observations of participants remained in the EFA group and 11 in the IFA group. This was associated with a loss to follow-up rate of 8.3% in the IFA group and 11.1% in the EFA group.

6.5.3.3 Sensitivity analysis 1 - imputation method- comparison EFA versus IFA

This sensitivity analysis compared the findings generated with a MI approach with an analysis using only data of all observed participants (CC: complete cases) at the retention test endpoint. The analysis of the primary outcome measure (APSPT 29) remained statistically insignificant (p: 0.93 CC versus p: 0.88 MI). But the direction changed for this outcome with the CC analysis favouring the EFA group (Table 6.18). With regard to the secondary outcome measures the different imputation methods did not change the group superiority or the statistical significance. In all but the analysis of the APSPT's sub-dimension "procedure execution" the use of MI increased the effect sizes to a small degree.

6.5.3.4 Sensitivity analysis 2 - correlation response time and procedure performance

To test whether a longer response time was associated with a higher performance the correlation between the APSPT 29 total score and the response time was analysed. There was a significant correlation (r: 0.32) between the two variables ($p < 0.004$). The correlation between the PSC total score and the response time (r: 0.31) was also statistically significant (p: 0.005).

Table 6.18 Sensitivity analysis – exploring the effect of the multiple imputation approach – comparison EFA (group 2C) versus IFA (group 2D)

Outcome measure		Retention test (T2) CCA			Retention test (T2) MI		
		Group 2C (n = 8) External focus of attention	Group 2D (n = 11) Internal focus of attention	Significance and effect size	Group 2C (n = 9) External focus of attention	Group 2D (n = 12) Internal focus of attention	Significance and effect size
APSPT 29 (0-116 points)	mean (SD)	69 (SD: 22.69)	71.54 (SD: 21.15)	W: 42.5, p: 0.93; r: - 0.02	70.67 (SD: 21.81)	73.08 (SD: 20.85)	W: 51.5, p: 0.88; r: - 0.03
	median (IQR)	77.5 (IQR: 32.5)	78 (IQR: 31)		81 (IQR: 26)	78.5 (IQR: 36)	
APSPT Subdimension PE (0-28 points)	mean (SD)	16.25 (SD: 6.96)	17.1 (SD: 6.63)	W: 49.5, p: 0.68 (*0.68); r: - 0.09	16.78 (SD: 6.7)	17.33 (SD: 6.37)	W: 49.5, p: 0.78 (*0.78); r: - 0.06
	median (IQR)	18.5 (IQR: 12)	19 (IQR: 11)		20 (IQR: 11)	19.5 (IQR: 10)	
PSC (0-26 points)	mean (SD)	16.75 (SD: 6.84)	20.27 (SD: 5.08)	W: 28, p: 0.19 (*0.48); r: - 0.28	16.89 (SD: 6.41)	20.58 (SD: 4.96)	W: 32, p: 0.13 (*0.26); r: - 0.33
	median (IQR)	19.5 (IQR: 9)	22 (IQR: 7.5)		18 (IQR: 7)	22.5 (IQR: 7.25)	
Response time (seconds)	mean (SD)	170.13 (SD: 37.25)	199.45 (SD: 57.49)	W: 29, p: 0.24 (*0.48); r: - 0.26	166.11 (SD: 36.86)	200.42 (SD: 54.92)	W: 31, p: 0.11 (*0.26); r: - 0.35
	median (IQR)	174 (IQR: 39.25)	190 (IQR: 37)		168 (IQR: 59)	199.5 (IQR: 31)	
Self-reported confidence (0-12 points)	mean (SD)	6.25 (SD: 2.92)	7.18 (SD: 2.96)	W: 35, p: 0.48 (*0.64); r: - 0.15	6.11 (SD: 2.76)	7.42 (SD: 2.94)	W: 38.5, p: 0.28 (*0.37); r: - 0.23
	median (IQR)	5.5 (IQR: 3.5)	7 (IQR: 4)		5 (IQR: 3)	7.5 (IQR: 4.25)	

Key. CCA: analysis of complete cases; MI: multiple imputation; p: p-value; *p-value corrected for multiple testing; PE: procedure execution; PSC: Procedure specific checklist; r: effect size; W: Wilkinson rank-sum statistic

6.6 Discussion - LEArN trial - task procedure 2 - vestibular rehabilitation procedure

The discussion of task procedure 2 of the LEArN trial is structured in three sections. First, the findings of the comparison MP against nMP are discussed. Then the comparison EFA versus IFA is discussed. The last section is related to general limitations of both comparisons.

6.6.1 Discussion comparison mental practice against no mental practice

6.6.1.1 Discussion of the effectiveness

The main finding of this comparison was that a statistically significant difference between MP and nMP group was not analysed at both endpoints on the APSPT 29 (p: 0.21 for the post-acquisition test and 0.99 for the retention test). The observed difference in medians was in favour of a procedural skills training with MP compared to a training using only physical practice. However, because the findings were not statically significant it is not possible to state that MP is more effective for skill acquisition of the vestibular rehabilitation procedure than nMP.
Furthermore, the group difference on the second outcome measure for procedural skills (PSC) was not statistically significant at the post-acquisition test (p: 0.43). A possible small trend in favour of the MP intervention analysed in this comparison (evidenced by a difference in medians and moderate effect sizes in favour of the MP group) is supported by evidence from studies performed in related disciplines (Arora et al. 2011) and was also found for task procedure 1 (i.e. transfer). However, at the retention test both groups performed similarly on the procedural performance indices and therefore while the median performance improved with MP in the current study it was not more effective for the longer-term learning of procedures.
Some issues were noted regarding the group performances on the APSPT 29 and the PSC. First, between post-acquisition and retention test both groups showed a decrease in performance on the APSPT 29 while the performance remained relatively constant on the PSC. This might be caused by different test situations (e.g. the procedure was performed on a peer during the post-acquisition test and a

simulated patient in the retention test). The APSPT 29 is a generic measurement of procedural skills and also incorporates items related to communication and patient comfort. In contrast, the PSC only evaluates whether a certain procedure step was adequately performed. Therefore, participants might have performed the adequate steps during the retention test (and scored relatively high on the PSC) but other aspects of procedural competency, which are necessary during a “real” practical encounter are to greater extent measured with the APSPT 29. This could explain the discrepancy between the two measurement instruments at retention.
Second, on both assessments of procedural competency it was noted that the group performance at the post-acquisition test was relatively homogenous. In contrast, a broad range of observations was evaluated at the retention test. This might be related to the individual learning processes. Some participants demonstrated indications of genuine learning and improved their performance while others showed a strong deterioration of their performance. Another variable might be the test situation as discussed above. The encounter of an unknown patient causes stress, which might have a different impact on the participants. Also, another explanation could be, before becoming skilled at a procedure there is often a decrement in performance before learning occurs and there is improvement (Shea and Morgan 1979).

Two outcomes showed interesting findings. First the median response time was longer in the group with the higher median performance ratings (i.e. APSPT 29 and PSC). A priori it was expected that with an increased performance a reduction in response time would be associated. For example, Starkes et al. (1998) reported that the time needed to perform a procedure in surgery was a good estimate of the individual’s procedural abilities. However, in this study the MP group (i.e. the group with the higher median performance rating) needed considerable more time than the nMP group at both endpoints. Two reasons might have caused the longer response time: i) non-motor aspects (such as an increased amount of information provided) and ii) adequate patient assessment. Providing instructions and post-procedure information were rated on both performance indices (APSPT 29 and PSC). A detailed patient instruction, which requires time, did therefore increase the performance rating. Second, to perform the vestibular assessment on both patient sides was scored on the assessments as well, which considerably increases the time needed to perform the procedure. Based on these arguments it can be hypothesised that increased procedural competency is not inevitably associated with a decreased response time in these complex manual procedures. Furthermore, the outcome “response time” should be evaluated cautiously in physiotherapy education and the assumption that a shorter response time indicates proficiency might not be valid in this setting.

The second outcome with unexpected findings was “mental practice abilities”. The MP group had a greater difference between imaged response time and physical response time at both endpoints. A priori it was expected that the MP would reduce this difference. Potential reasons for this unexpected finding were already discussed in section 6.4.1.1 and are related to: i) an insufficient amount of MP or ii) non-automated movement skills and are therefore not presented here again.

Within this comparison the group with the higher performance ratings (i.e. MP group) also rated their self-confidence to perform the procedure higher than the other group. This was expected, but different from the findings of task procedure 1 where the opposite was observed. The main variable that differed between the two parts was the procedure that was practiced. Therefore, the difference might be related to this circumstance. On the other hand, with a relatively small sample size a small study bias might have occurred.

Lastly, the analysis of the APSPT procedure execution subdomain showed a greater between group difference than the APSPT total score at post-acquisition. This might indicate that the MP intervention especially increased motor skills related factors such as hand placement or the therapist’s body position. However, as the findings were not statistically significant this remains speculative.

6.6.1.2 Discussion of feasibility

The main finding of the feasibility analysis for the MP against nMP comparison was that the feasibility of the study was high based on quantitative feasibility measures. The observed recruitment rate was very high, the failure rate was very low at the post-acquisition endpoint and although the failure rate increased at the retention test both groups remained below the pre-defined 40% threshold and finally all participants completed both endpoints with no loss to follow-up. The increased failure rate at the retention test indicates that genuine learning did not occur in all participants and for parts of the sample more practice would be required.

A key feasibility issue noted was that some participants felt challenged with the MP intervention. MP is not a standard intervention and it is difficult to use a new training principle for the first time. Some participants stated that it was difficult to perform a MP of the procedures because of the surrounding noise. In a future study this should be addressed. For example, all participants should be reminded to be calm, or be offered private practice rooms. However, considerably more resources would be required. Regarding the issue that the MP is a novel practice regime one might propose to increase the instruction time in the MP group. This was avoided because additional instruction time could be regarded as potential confounder, which might affect the effectiveness of the intervention. Therefore, a challenge remains for future studies to increase the feasibility of the MP intervention and potential barriers should be identified and removed. Despite, these feasibility issues the MP group performed better than the nMP group on the main performance indices. Therefore, increasing the feasibility of the training would potentially further augment the effectiveness of the MP intervention.

A challenge reported by the participants, which was not related to the group allocation was the visualisation of the vestibular system during the training. This issue should be addressed in future studies or during routine procedural skills training involving this procedure (e.g. by providing anatomical models).

It was found that the evaluations of video performance were particularly time-consuming and this might affect widespread adoption of the outcome measure. Especially, the APSPT 29 required substantial time to complete. In contrast to the PSC, which could be completed relatively fast. The APSPT's item all require time to think because they are "indirectly" evaluated. For example, the item "adequate hand placement" should be evaluated over the complete procedure. In contrast, an item of the PSC would require the assessor to evaluate whether the hands are adequately placed in a certain step. In order to increase the feasibility and reduce the resources of a future study it might be attractive to use only one assessment and the PSC would be a pragmatic choice. However, certain valuable more holistic information would not be available for the evaluation (such as communication or decision-making items). But recently Lohse et al. (2016) reported that studies in motor learning research tend to use "too" many assessments and therefore a reduction in the number of outcome measures was recommended to avoid the problems associated with testing group performance on multiple similar outcome measures.

A major challenge for a follow-up study is the required sample size. Based on the APSPT 29 effect size generated by this study, 150 participants would be required. Recruiting such a sample would exceed the possibilities of a single site and a multi-centre design with considerable more resources, and potentially more confounding variables, would be needed. However, a larger study over multiple sites would allow greater potential to generalise findings.

Analysis of common mistakes revealed that frequently errors were not only related to motor skills. For example, some errors were attributed to decision-making or patient information, which are key components in physiotherapy interactions and this was not fully controlled for in this study.

Originally, MP was chosen as the training principle for this study because evidence exists that this training method increases the acquisition of motor skills (Sattelmayer et al. 2016a). This study showed that MP seemed to benefit procedural performance, and indicates that it might be possible to apply this learning principle to procedures that are not limited to motor skills and involve other sub-dimensions of procedural skills.

6.6.2 Discussion comparison external focus versus internal focus of attention

First, the results of the effectiveness analysis are discussed and then the feasibility of this comparison is discussed.

6.6.2.1 Discussion of the effectiveness

The main finding of the comparison EFA versus IFA was that the performance of both groups was relatively similar on the primary outcome measure (APSPT 29) at both endpoints. On the secondary performance measure (PSC) the performance of the IFA group was slightly higher at both endpoints but the effect size remained small to moderate without reaching statistical significance. This showed that there was no relevant difference between both groups regarding their performances at both endpoints.

This finding deviated from the analysis of the acquisition of a transfer procedure. There, the IFA group showed statistically significant results on the APSPT 29 in favour of the IFA group at the post-acquisition test (p: 0.04) and non-significant results at the retention test (p: 0.06). This trend could not be seen in this analysis. Furthermore, the findings deviated from the findings in the literature where an EFA approach is frequently associated with more effectiveness (e.g. Wulf 2007). One potentially relevant variable, which might explain the findings is the complexity of the procedure. Previously, it was discussed that procedures appraised as very complex on Gentile's framework (2000) seemed to benefit more from IFA interventions (section 3.3.2.3 (i.e. meta-regression attentional focus). In contrast, less complex procedures benefitted more from EFA interventions. The complexity of the vestibular rehabilitation procedure was appraised based on the following assumptions: i) the regulatory conditions of the environment were difficult to classify with a dichotomous approach as suggest by Gentile. Environmental conditions were relatively stable, that is the supporting surface did not move, and the patient's movements might be predicted to a certain degree. However, unexpected movements occur and introduce some in-motion characteristics. Therefore, in-motion conditions were assumed, ii) the procedure pattern is standardised with defined steps that should not be changed. This was appraised as no or only minimal intertrial variability, iii) the procedure requires a body transport (i.e. an active change of location is involved) and iv) the therapist needs to control specific body parts of the patient (i.e. object manipulation was assumed). This led to a complexity of 3D on Gentile's framework when regulatory environmental conditions were assumed. The meta-regression presented in section 3.3.2.3 predicted equal effectiveness between EFA and IFA at this level. This presents further evidence that the task complexity is a relevant variable when deciding, which attentional focus should be used.

The vestibular rehabilitation procedure is considerably less complex than the transfer procedure where the therapists needs to control an unstable system with a much larger degree of unpredictable patient movements. On the other hand, there are other challenges associated with this procedure. For example, the cognitive challenges to visualise the vestibular system or the interpretation of the test result and selection of the appropriate intervention. One could argue that these challenges are less likely to be influenced by an attentional focus. An attentional focus might be more useful when the emphasis of the skill is mainly on motor control

An implication for educators would be to classify the challenges of the procedure such as their cognitive, decision-making and required motor skills. The selection of an attentional focus would require an emphasis on motor skills. The following step would be to classify the procedure regarding its complexity and to decide whether to use an internal or EFA.

Despite similar performance ratings on the primary outcome measure the IFA group showed a higher self-reported confidence. This effect came unexpectedly as the self-reported confidence in the EFA group was higher for task procedure 1. However, the between group difference regarding the performance ratings was much higher than in this sub-study. Furthermore, the questionnaire used to evaluate the self-reported confidence was validated in a study with a population of medical students performing surgical procedures (Sanders et al. 2008). For this study the questions, which were surgery specific were not used. Therefore, only three of six questions remained to evaluate the self-reported confidence. This might have caused that some aspects of the self-reported confidence were missed in this study and a bias might have occurred. The construct "self-reported confidence" should be explored in more detail in this specific setting, which could provide more details regarding the assessment of this construct.

6.6.2.2 Discussion of the feasibility

The discussion on the feasibility of this comparison briefly presents novel points that have not already been discussed for the other comparisons.

A feasibility issue, which occurred during the instructions of the procedure was that more time was needed in the IFA group. This was caused by questions, which were raised by the participants during the session. This should be modified in a future study. One approach could be to postpone questions to the end of the instruction session. The prolonged instruction time might have caused the participants in the IFA group to have a shorter practice time. All participants were asked to practice until they felt that they were competent to perform the procedure. However, two participants in the IFA group mentioned in the follow-up questionnaires that they would have liked additional practice time. This might be caused by the practice situation. The participants practiced in pairs and when one participant indicated that sufficient competence was reached the other might have agreed to this but still felt the need for practice. A possible mechanism to prevent this would be to set a certain amount of practice trials. However, there are no established guides for the adequate amount of practice trials in this setting and possibly this would vary between participants as well.

To illustrate the challenge to define an accepted amount of practice trials the following example is presented. Lammers et al. (2008) reported in their consensus guideline for teaching and assessing procedural skills that the number of repetitions required to achieve skill acquisition is not clearly defined and probably varies for different procedural skills. For, example Wayne et al. (2008) reported that 93% of their participants achieved skill acquisition of a surgical procedure after 4 hours of practice. But it is difficult to use this time scale to inform about a procedure in physiotherapy education.

Providing the different instructions in both groups was very challenging. Recordings of the skills training session confirmed that no mistakes occurred. Large resources were needed to achieve this. Considering the required resources and the limited effectiveness of the two attentional foci it might be more pragmatic to use other motor learning principles for this procedure. As a consequence of the small between group difference the required sample size for a follow-up study would be very large and probably too large to be feasible.

6.6.3 General limitations - both comparisons

Within this section general limitations are presented. First, in total 40 participants were allocated to two comparisons. The group size varied between nine and 12 participants. The sample size is therefore small and a small study bias cannot be excluded. Treatment effects tend, on average, to be more beneficial in small studies (Nüesch et al. 2010). It could be argued that a restriction to one motor learning principle and one procedure would have decreased the risk of this bias considerably. But the application of motor learning principles to the field of HPE is relatively novel. Only few studies set out to explore the effects of MP (Sattelmayer et al. 2016a). Furthermore, the available evidence is mainly based in medical education (mostly surgical procedures) and no evidence is available in physiotherapy education where considerable patient interaction can confound findings. Regarding the FoA, no randomised control trials were found that explore the effectiveness in HPE. Therefore, this study was designed as a pilot study to explore possible effectiveness and feasibility and identify potential situations where these interventions might be used in an educational setting. Furthermore, sound epidemiological methods were used to reduce the risk of bias related to other sources such as selection bias (e.g. central allocation), detection bias (e.g. blind outcome assessment) and attrition bias. With respect to performance bias it might be expected that the participants in the

EFA versus IFA comparison were not aware of their group allocation. In contrast, this risk of bias cannot be excluded for the MP comparison. In conclusion, the limitations associated with the sample size and the results should be viewed with caution.

A further limitation was the baseline difference regarding gender (i.e. considerably more male participants were allocated to group 2D). This could have been prevented by stratification of this variable. However, previous academic performance was considered as a more important confounding variable than gender. Therefore, a stratified randomisation was applied to balance this variable between groups.

Another limitation was that the MP script for the set of procedures from vestibular rehabilitation was developed based on literature instructions (Herdman and Clendaniel 2014). Therefore, the MP of this procedure was not validated a priori. Despite this limitation the effect sizes in favour of MP were similar for the transfer and vestibular rehabilitation procedure.

Then, ethical implications are associated with this study design. The primary investigator and the participants were all affiliated with the UAS Valais and a power difference exists, which might have caused participants to feel obligated to participate. Recruitment rate and follow-up rate were high, which might indicate this. However, appropriate measures to avoid such a feeling were presented to the ethical committee of QMU and ethical clearing was granted and there was a low drop-out rate.

A possible limitation (for both comparisons) was that the procedure was performed on a peer during the post-acquisition test and a simulated patient was used for the retention test. One might argue that the test conditions were different between both endpoints and consequently it is difficult to compare the data of both endpoints. These limitations are true. The reason why different test conditions were chosen was to integrate a transfer element in the retention test (i.e. the participant is requested to perform the skill in a context different from the practice situation (Magill and Anderson 2014)). The ability to transfer a skill to a different context is regarded as one indicator to differentiate between learning and performance (Wulf et al. 2010; Magill and Anderson 2014).

A further limitation was that the imputation method used deviated from the approach stated in the protocol. Reasons for the use of MI instead of the LOCF approach were already explained are therefore not reiterated here. Furthermore, only few values were imputed due to the high follow-up rate and a sensitivity analysis showed only a small influence of the imputation method.

Last, the between group changes on the APSPT 29 were relatively small for all comparisons. Only the EFA versus IFA comparison of the transfer procedure showed a difference of 10% of the APSPT total score. It is questionable whether the observed small amounts of difference are sufficient to reach a minimal (educational) important difference. Future studies should set out to determine the minimal important difference for skill acquisition in physiotherapy education.

6.6.4 Conclusion - acquisition of vestibular rehabilitation procedures

The comparison MP against nMP did not show statistically significant findings. Therefore, it is not possible to state that MP has an additional benefit on skill acquisition. The use of MP in a physiotherapeutic educational setting is feasible and should be further explored in follow up studies with a considerably larger sample size and a variety of tasks. The findings of the comparison EFA versus IFA do not allow strong conclusions regarding its effectiveness. Both interventions showed similar findings when used for the vestibular rehabilitation procedure. In contrast, for the transfer procedure the analysis showed statistically significant findings in favour of the IFA group at the post-acquisition test (p: 0.04). However, this trend was not observed at the retention test (p: 0.06). Therefore, educators should carefully appraise the practiced procedure to select an appropriate educational intervention. Procedures might be classified regarding their required procedural sub-dimensions such as decision-making, motor skills or communication. Based on the preliminary findings of this study procedures requiring adequate motor skills might be instructed with an IFA or EFA. Highly complex motor skills might be instructed with an IFA and less complex motor skills with an EFA. The application of Gentile's framework (Gentile 2000) to classify procedural complexity seemed to be useful but modifications to adapt the framework to procedures in physiotherapy education might be considered. If the procedural demands are not geared to the sub-dimension "motor skills", the use of MP might be more effective to support the acquisition of skills. This proposed selection rule is based on the findings of this pilot study and should be further investigated and validated and certainly needs stronger evidence before it can confidently be advocated as an approach in educational practice.

The variables “self-reported confidence” and “response time” require further investigation as the results generated had not been expected. Finally, the results of this study should be interpreted and applied with caution as this report is based on a small sample and from one site. Therefore, studies with sufficient power should be designed to explore the findings of this pilot study.

7 Conclusion and implications

This thesis has reported work undertaken for the dissertation of a Professional Doctorate programme with an aim to advance practice. This final chapter provides a brief general discussion of chapters 2 - 6 along with key findings, implications for practice and suggestions for future research. In Table 7.1 the key findings of the thesis are presented.

The work is highly relevant to practice as the World Confederation for Physical Therapy have stated that procedural skills are a central element in the education of future physiotherapists (2011; 2017). Based on this statement, various aspects related to the acquisition of procedures in physiotherapy education, among others the application of two innovative educational interventions were analysed.

Table 7.1 Key findings of the thesis

Chapter	Key findings
Chapter 2: Definition of procedural skills	The majority of published systematic reviews and randomised controlled trials investigating the acquisition of procedural skills did not report or adequately define the concept “procedural skills“. “Execution of a motor skill” is a key sub-concept of procedural skills. Several other sub-concepts were identified such as “safety” and “decision-making”. Manual tasks can be considered as central element of procedural skills in physiotherapy education. A new definition of procedural skills was proposed, which can be used in research and education.
Chapter 3: Systematic review effectiveness of attentional foci	Performance at post-acquisition was higher in groups using an external focus of attention versus an internal focus of attention (SMD: -0.54, 95%CI: -0.86 to -0.22). Findings of retention and transfer tests were in favour of an external focus of attention. Skill complexity was identified as potential important predictor variable. Highly complex motor skills seemed to benefit more from an internal focus of attention. High risk of bias of included studies.
Chapter 4: Analysis of mental practice interventions	The concept “mental practice” was defined as “mental rehearsal of a procedure” in all included studies. Terminology differed between studies some referred to “mental practice” while others used the term “mental imaging”

	Considerable heterogeneity was analysed regarding the structure of the mental practice interventions. The majority of studies did not adhere to all best practice criteria of mental practice.
Chapter 5: Development of a mental practice script	Expert interviews revealed a considerable number of cues, which were used to develop a mental practice script. The majority of identified cues were kinaesthetic, other cues were classified as cognitive, visual or collaborative. The ability to mentally image a transfer procedure after a mental practice session with the script increased considerably.
Chapter 6: LEArN Trial	The feasibility of the LEArN trial was high for both motor learning principles (mental practice and focus of attention) The observed difference of medians was in favour of mental practice with a moderate effect size. The results were not statistically significant for the transfer procedure (p: 0.2) and the vestibular rehabilitation procedure (p: 0.21) at post-acquisition testing. An internal focus of attention seemed to be superior to an external focus of attention for the transfer procedure (p: 0.04) at post-acquisition testing. A similar performance was observed between an external and internal focus of attention for the vestibular rehabilitation procedure.

A key conclusion of **Chapter 2** is that the concept of procedural skills is multifaceted and involves several sub-concepts. Execution of a motor skill is the central element of procedural skills in physiotherapy education. “Safety” and “knowledge” were identified as further key elements. Furthermore, communication and decision-making processes must be acquired to adequately perform physiotherapeutic procedures. When procedures are performed in combination with patients, “patient focussed interaction abilities” are essential. In addition, it was appraised that manual tasks are a central element in physiotherapeutic procedures. Educators are advised to take this complexity of procedural into account when educational interventions for procedural skills are developed. Neglecting some of the sub-concepts might create a barrier in the process of skill acquisition.

Furthermore, it is recommended to use assessments covering the whole spectrum of procedural skills such as the APSPT 29. The information gained might help educators to tailor their educational interventions to specific problems of individual students.

Based on the findings of **Chapter 3** it can be concluded that an EFA was superior to an IFA on performance at post-acquisition, retention and transfer tests for the acquisition of complex, real world motor skills. However, meta-regression identified one potential important variable (i.e. "skill complexity), which might be used to predict the success of different FoA interventions. An EFA was superior for motor skills with a low to moderate degree of skill complexity and an IFA seemed to be superior for skills with a high level of skill complexity. However, this finding was statistically not significant and should be further investigated.
Educators are recommended to use an EFA for skill acquisition of real-world sport related motor skills. Furthermore, it may be essential to appraise the complexity of the motor skills to be practiced. Preliminary evidence suggested that motor skills with a rating of low and moderate should be instructed and practiced with an EFA. For highly complex skills an IFA seemed to be more effective. However, this is not certain and future studies are needed to support this statement. A final recommendation of this chapter is to explore the FoA motor learning principle in various HPE settings.

One main conclusion of **Chapter 4** is, that MP is homogenously defined in studies using this intervention in HPE as the "mental rehearsal" of a task. In contrast, considerable heterogeneity existed regarding design, structure and dose of MP interventions. Therefore, studies should set out to explore the optimal structure of a MP intervention in HPE. For example, it should be analysed whether additional relaxation exercises can be used to increase the effectiveness of MP. A key limitation of studies using MP is that the amount or dose of independent MP is only rarely controlled for and can be challenging to ascertain.

The key conclusion of **Chapter 5** was that it was possible to develop a MP script in physiotherapy education based on an approach presented by Arora and colleagues (2010). The analysis of the expert interviews revealed that cues from different categories were reported from the experienced physiotherapists (i.e. kinaesthetic, cognitive, visual and collaborative). Most cues were categorised as kinaesthetic cues, indicating that this information may be important during the skill acquisition process. Future studies exploring MP in HPE are encouraged to design their interventions based on an approach that incorporates sound principles such as expert interviews, a systematic identification of MP cues within the interviews and validation work to structure their MP interventions to adhere to proposed benchmarks of MP. When using MP, educators are encouraged to explore cues for procedures in physiotherapy education. The integration of cues from different modalities may provide a rich experience of the procedure to be practiced mentally. More studies are required designing and validating MP scripts for different procedures in physiotherapy education.

The findings of **Chapter 6** showed that it is feasible to use the motor learning principles MP and FoA in physiotherapy education to acquire complex procedural skills. The effectiveness analysis showed that there was no statistically significant difference between MP and nMP. However, the observed median performances were in favour of MP for both task procedures. This may suggest a possible trend in favour of MP. However, this remains speculative in the light of the statistically non-significant results and it is not possible to state that MP is more effective than nMP in physiotherapy education. The analysis of the FoA comparison showed that an IFA was more effective than an EFA for a transfer procedure at post-acquisition testing but both FoA groups showed a similar performance with regard to vestibular rehabilitation.

Recommendations for research-are i) to evaluate the effectiveness of MP versus nMP and EFA versus IFA for complex skill acquisition in future studies with a larger sample size and ii) to analyse the effectiveness of the motor learning principles on other procedures in physiotherapy education. No clear recommendation can be made for practice regarding MP. It might be possible that MP is useful for skill acquisition, but more studies are needed to investigate the effectiveness prior to the routine use of this motor learning principle in physiotherapy education. Educators are cautiously recommended to use an IFA for highly complex procedures.

7.1 Overall conclusion

This thesis presented evidence that two motor learning principles can be used in physiotherapy education. This was the first research to use the principles in this setting. Based on the evidence, educators are informed that is possible to integrate both motor learning principles (MP and FoA) into their professional practice when teaching new skills. The proposed motor learning principles are a pragmatic choice to support the acquisition of procedures in physiotherapy education. Especially, for the FoA principle, the skill to be acquired should involve motor skills. Procedural skills with no or only a limited amount of required motor skills should be acquired with other educational interventions. Educators should be aware that these recommendations may be subject to change. Future studies might change the effect sizes of the comparisons because the recruited sample size was small and a potential small study bias cannot be excluded.

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9 Appendices

Table of appendices

Appendix i Search strategy used in chapter 2

(procedural skill*) AND (((((((((randomized controlled trial[pt]) OR controlled clinical trial[pt]) OR randomized[tiab]) OR placebo[tiab]) OR drug therapy[sh]) OR randomly[tiab]) OR trial[tiab]) OR groups[tiab])) NOT ((animals[mh] NOT humans[mh])))

Appendix ii Gentile's taxonomy

Gentile's taxonomy (2000) is presented below.

Gentile's taxonomy			**Action Function**			
			Body Stability		**Body Transport**	
			No Object Manipulation	**Object Manipulation**	**No Object Manipulation**	**Object Manipulation**
Environ-mental Context	**Stationary Regulatory Conditions**	**No Intertrial Variability**	1A Body Stability No Object Stationary Reg. Cond. No Intertrial Variability	1B Body stability Object Stationary Reg. Cond. No Intertrial Variability	1C Body Transport No Object Stationary Reg. Cond. No Intertrial Variability	1D Body Transport Object Stationary Reg. Cond. No Intertrial Variability
		Intertrial Variability	2A Body Stability No Object Stationary Reg. Cond. Intertrial Variability	2B Body stability Object Stationary Reg. Cond. Intertrial Variability	2C Body Transport No Object Stationary Reg. Cond. Intertrial Variability	2D Body Transport Object Stationary Reg. Cond. Intertrial Variability
	In-Motion Conditions	**No Intertrial Variability**	3A Body Stability No Object In-Motion Cond. No Intertrial Variability	3B Body stability Object In-Motion Cond. No Intertrial Variability	3C Body Transport No Object In-Motion Cond. No Intertrial Variability	3D Body Transport Object In-Motion Cond. No Intertrial Variability
		Intertrial Variability	4A Body stability No object In-Motion Cond. Intertrial Variability	4B Body stability Object In-Motion Cond. Intertrial Variability	4C Body Transport No Object In-Motion Cond. Intertrial Variability	4D Body Transport Object In-Motion Cond. Intertrial Variability

The different variables were defined as presented in Magill and Anderson (2014):

Stationary regulatory conditions: "Spatial features of the environment control spatial movement characteristics of an action; the timing of the initiation of an action is controlled by the performer" (Magill and Anderson 2014, p. 14).

In-motion regulatory conditions: "Spatial and timing features of the environment control spatial movement characteristics and timing of the initiation of an action" (Magill and Anderson 2014, p. 14).

Body stability "refers to skills that involve no change in body location during the performance of the skill" (Magill and Anderson 2014, p. 15).

Body transport refers to skills "that require the body to move from one place to another" (Magill and Anderson 2014, p. 15).

Object manipulation refers to "maintaining or changing the position of an object" (Magill and Anderson 2014, p. 16).

Appendix iii Parts and corresponding cues of the transfer to the ground procedure

Step	Movement task	Type of Cue	Imagery cue
Preparation	General information for the complete procedure	Collaborative	Assure that the patient feels safe in every step
		Collaborative	When the patient is situated in a certain position. Ask him to make small displacements with his centre of mass to reach the best possible balance.
		Cognitive	The weight shift is the search for a point were the patient is in balance. When the point is reached it becomes easy for the patient to control the movement (add visual image medio-lateral and dorso-frontal).
Step 1	The patient is sitting on a bench and is instructed to turn his body to the stronger side.	Collaborative	Take enough time to explain the procedure to the patient.
		Kinaesthetic	Place your hands on the pelvis and assist the turning movement to the stronger side.
Step 2	The patient is asked to place the weaker knee on the ground. The physiotherapist supports the weaker hip.	Cognitive	Take care that the patient is not falling from the bench.
		Kinaesthetic	Stabilise the patient's weaker hip and prevent that the patient is falling to the side when he touches the floor with his knee.
		Collaborative	If you have the feeling that you and the patient are stable you ask the patient to place weight on his knees.
		Collaborative	It is important that you have a stable stance and move with the patient.
Step 3	The patient places the stronger knee on the ground and is situated in knee-standing.	Collaborative	Ask the patient to perform a weight shift towards the weaker knee and to place the stronger knee on the ground.
		Kinaesthetic	Feel if the patient places weight on his weaker knee
		Kinaesthetic	Control the patient's hip extension with your knee.
		Collaborative	Provide enough stability, so that the patient can start to move the stronger leg.
Step 4	The patient is instructed to place both arms on the ground.	Cognitive	If the patient needs much support in knee-standing prepare to provide enough support
		Kinaesthetic	Support the downward bending of the patient. Provide support with one hand on the trunk (sternum) and your knees at the patient hips.
		Kinaesthetic	Control and stabilise the patient's shoulder. Feel how much shoulder muscle activity is generated by the patient.
Step 5	The patient is instructed to sit down on one side.	Cognitive	Make a decision to go over the weaker or over the stronger side. Possible reasons to go over the stronger side are pain, severe shoulder or trunk instability, subluxation or you do not know the patient well.
		Kinaesthetic	Control the weight shift with your knees.
		Kinaesthetic	One hand is placed on the trunk (e.g. sternum) to reduce the weight on the weaker
		Kinaesthetic	The patient slides slowly down over your legs.
		Kinaesthetic	Place your feet under the patient. If the movement is too fast he will land on your feet.
Step 6	The patient is instructed to lie on the mat.	Collaborative	Instruct a smooth movement.
		Kinaesthetic	One hand is placed on the trunk (e.g. sternum) to reduce the weight on the weaker
		Kinaesthetic	Feel if the shoulder is stable. If unstable guide the patient to the floor and place him on
Step 7	The patient is instructed to raise the trunk and place load on the elbow and extent	Collaborative	Take enough time to explain the procedure to the patient.
		Cognitive	Use the same side as you used in the first part. Reasons for the stronger side are pain
		Kinaesthetic	Control and support the trunk with one hand.
		Kinaesthetic	Control and support the shoulder with one hand.
Step 8	The patient is instructed to move into a quadruped position	Kinaesthetic	Place your hands on the patient's pelvis. Or if the trunk needs stabilisation place one
		Collaborative	Anticipate the patient's arm and leg positions when he reaches the quadruped position.
		Collaborative	Place your feet in a way that the patient is between your legs in the quadruped position.
		Collaborative	Instruct a fast swinging movement and give a clear starting signal.
Step 9	The patient is instructed to move into a knee-standing position	Collaborative	Ask the patient to "walk" with his hands towards his knees until he reaches a knee-
		Kinaesthetic	Stand behind the patient. Your knees stabilise the patient's hips. If you feel too much pressure, the patient might not be able to extend his hip s and sit on his heels.
		Kinaesthetic	Initially allow a small backward movement of the patient's hips. This is followed by a forward movement when he extends his hips.
		Kinaesthetic	Your hands stabilise the trunk.
Step 10	The patient is asked to raise one leg. The physiotherapist supports the weaker hip.	Cognitive	Decide whether you perform this step with the stronger or weaker leg. If the weaker leg is raised the remaining movements are harder to perform.
		Cognitive	When the patient is in a knee standing position you can ask him to perform weight shifts towards the stance leg. Try to find a point where the other leg is free to move.
		Kinaesthetic	Stand behind the patient. Your knees stabilise the patient's hip.
Step 11	The patient is asked to place the stronger arm on the treatment table	Cognitive	Ask the patient to swing with momentum on the treatment table.
		Kinaesthetic	Control if the patient uses his arm to support the movement.
		Kinaesthetic	Place your hands on the patient's pelvis and assist the movement.
	Total cues	**42**	**Kinaesthetic: 21; Cognitive: 7; Collaborative: 14; Visual: 0**

Information Sheet for Potential Participants

My name is Martin Sattelmayer and I am a lecturer in Physiotherapy at University of Applied Arts and Sciences Western Switzerland Valais-Wallis as well as being a postgraduate Professional Doctoral student from the School of Heath Sciences at Queen Margaret University in Edinburgh. As part of my Doctorate, I am undertaking a research project. The title of my project is: “Learning of procedures in physiotherapy education”.

This study will investigate the effectiveness of different motor learning principles on the learning of procedures in physiotherapy education.

Why should I take part?
The findings of the project will be valuable because we might be able to identify the benefits of using different methods and future physiotherapy students could benefit from more effective teaching methods.

Am I eligible to take part?
I am looking for volunteers to participate in the project. The criteria for inclusion are:

- You are a 2nd or 3rd year undergraduate physiotherapy student

There is only one exclusion criterion:

- You should have no prior formal training with regard to the following procedures: specific procedures in vestibular rehabilitation or a transfer procedure to the ground with a stroke patient).

What will happen if I take part?
If you agree to participate in the study, you will be asked to attend a procedural skills training where you will practice a practical skill. The duration of the procedural skills training is 2 hours. Furthermore, you will be asked to perform the procedure immediately after the practice session in a first test. A second test will be scheduled two weeks after the training session. Both test sessions will have a duration of 20 minutes and will be video recorded. The research team is not aware of any physical or psychological risks associated with study. Your performance during the study will have no influence on your student status or your grades at the UAS Valais. To assure this the video recordings will be evaluated by external assessors not involved in teaching at the UAS Valais-Wallis.

Do I have to take part?
You are under no obligation to take part. If you do take part, you will be free to withdraw from the study at any stage and you would not have to give a reason.

Will I be identified in any findings?
No. All data will be anonymised as much as possible, and for any paper records

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your name will be replaced by a code. It is very unlikely that the external assessors will recognise you on the video recordings, as they will not have had teaching contact with you.
In any reports Your name will be replaced with a participant number, and it will not be possible for you to be identified in any reporting of the data gathered.

The results may be published in a journal or presented at a conference.

If you would like to contact an independent person, who knows about this project but is not involved in it, you are welcome to contact Professor Roger Hilfiker. His contact details are given below.

If you have read and understood this information sheet, any questions you had have been answered, and you would like to be a participant in the study, please now see the consent form.

Contact details of the researcher

Name of researcher:	Martin Sattelmayer
Address:	University of Applied Arts and Sciences Western Switzerland (HES-SO Valais-Wallis) School of Health Sciences, Physiotherapy 3954 Leukerbad Switzerland Queen Margaret University, Edinburgh Queen Margaret University Drive Musselburgh East Lothian EH21 6UU
Email / telephone:	martin.sattelmayer@hevs.ch; / +41 76 233 41 17 13007464@qmu.ac.uk

Contact details of the independent adviser (note that the independent adviser cannot be a member of your supervisory team)

Name of adviser:	Prof Roger Hilfiker
Address:	School of Health Sciences, University of Applied Sciences and Arts Western Switzerland Valais (HES-SO Valais-Wallis), CH-3954, Leukerbad Switzerland
Email:	roger.hilfiker@hevs.ch / +41 79 688 34 90

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Appendix v Approval commission cantonale d'éthique de la recherche sur l'être humain (CER-VD) Switzerland

From: scientifique.cer@vd.ch
Subject: RE: A TRAITER Tr : Category of research project
Date: 8 December 2016 at 11:41
To: martin.sattelmayer@gmail.com

S

Dear Mr Sattelmayer,

After internal discussions, we realized that your project is conducted with your students, the main purpose being training.

Moreover your project dos not involve collection of health-related personal data.

Therefore your project does not need to be submitted for approval to the CER-VD.

Kind regards

Secrétariat scientifique
Commission cantonale (VD) d'éthique de la recherche sur l'être humain
Av. de Chailly 23
1012 Lausanne
www.cer-vd.ch

From: **Martin, Dawn** DMartin1@qmu.ac.uk
Subject: Confirmation of Ethical Approval
Date: 9 February 2017 at 17:43
To: martin.sattelmayr@gmail.com, SATTELMAYER, MARTIN 13007464@qmu.ac.uk
Cc: Macmillan, Fiona FMacmillan@qmu.ac.uk, Baer, Gillian GBaer@qmu.ac.uk, Jagadamma, Kavi KJagadamma@qmu.ac.uk

MD

Dear Martin

Full title: Feasibility and effectiveness of motor learning principles on the learning of procedures in physiotherapy education: A development of concept study
Short title: Learning of procedures in physiotherapy education

Thank you for your application for ethical approval for the above named project. I am pleased to confirm that the reviewers and Ethics Panel Convener, Dr Chee-Wee Tan, are happy to grant full ethical approval for your research. For the avoidance of any doubt, this means that no further information or submission is required on your part at this stage.

A standard condition of ethical approval is that you are required to notify the Panel, in advance, of any significant proposed deviation from the original protocol. The relevant form for this is available at the link below:

http://www.qmu.ac.uk/quality/rs/default.htm

Reports to the panel are also required once the research is underway if there are any unexpected results or events that raise questions about the safety of the research.

We would like wish you well with your project.

Yours sincerely

Dawn Martin
Assistant Secretary, Governance and Quality Enhancement
On behalf of the Research Ethics Panel

Dawn Martin
Assistant Secretary, Governance and Quality Enhancement
Queen Margaret University
Edinburgh
EH21 6UU

Telephone: 0131 474 0000

Hes·so VALAIS WALLIS School of Health Sciences

Queen Margaret University

Case report form: Assessment of Procedural Skills in Physiotherapy Education

Date:

Procedure:

Participant ID:

Rater:

Overall assessment	Detailed assessment

Preparation

Overall assessment preparation

0 Very poor | 1 Poor | 2 Adequate | 3 Good | 4 Very good | ☐ Not assessed

Plans procedure with regard to patient factors

0 Very poor | 1 Poor | 2 Adequate | 3 Good | 4 Very good | ☐ Not assessed

Checks and prepares environment

0 Very poor | 1 Poor | 2 Adequate | 3 Good | 4 Very good | ☐ Not assessed

Adequate assessment is performed before the procedure

0 Very poor | 1 Poor | 2 Adequate | 3 Good | 4 Very good | ☐ Not assessed

Prepares patient appropriately

0 Very poor | 1 Poor | 2 Adequate | 3 Good | 4 Very good | ☐ Not assessed

Knowledge & Decision-making

Overall assessment knowledge & Decision-making

0 Very poor | 1 Poor | 2 Adequate | 3 Good | 4 Very good | ☐ Not assessed

Shows knowledge of the procedure

0 Very poor | 1 Poor | 2 Adequate | 3 Good | 4 Very good | ☐ Not assessed

Shows knowledge of the steps of the procedure

0 Very poor | 1 Poor | 2 Adequate | 3 Good | 4 Very good | ☐ Not assessed

Identifies appropriate procedure

0 Very poor | 1 Poor | 2 Adequate | 3 Good | 4 Very good | ☐ Not assessed

Safety

Overall assessment safety

0 Very poor | 1 Poor | 2 Adequate | 3 Good | 4 Very good | ☐ Not assessed

Ensures other's safety

0 Very poor | 1 Poor | 2 Adequate | 3 Good | 4 Very good | ☐ Not assessed

Ensures own safety

0 Very poor | 1 Poor | 2 Adequate | 3 Good | 4 Very good | ☐ Not assessed

Overall assessment	**Detailed assessment**

Communication

Overall assessment communication

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Provides information about procedure

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Tells the patient to state if there is any pain or discomfort

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Communication during procedure

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Avoids jargon

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Asks if the patient has any questions

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Procedure execution

Overall assessment procedure execution

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Appropriate hand and finger placement

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Performs procedure correctly

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Appropriate body position

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Anticipates next step

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Uninterrupted flow of the procedure

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Appropriately adapts procedure to the patient

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Overall assessment	Detailed assessment

Comfort

Overall assessment comfort

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Appropriate patient positioning

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Responses to patient discomfort

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Cues patient before touching

0	1	2	3	4	☐
Very poor	Poor	Adequate	Good	Very good	Not assessed

Total score:

Remarks:

Queen Margaret University
EDINBURGH

Case report form: Procedure specific checklist "Transfer procedure"

Date:

Participant ID: ☐ **Rater:** ☐

Instructions:

Two points will be awarded to a correct performance, one point will be given if the performance is performed with minor mistakes and zero points will be given if the item is performed with major mistakes or omitted.

Step	Description of steps	Scores (2,1 or 0)
Pre	The patient is adequately informed and prepared for the procedure.	
Down		
1	The patient is instructed to turn the stronger side on the bench and the therapist adequately assists the movement.	
2	The patient is instructed to place the weaker knee on the ground and the therapist adequately assists the movement.	
3	The patient is instructed to places the stronger knee on the ground and is situated in knee-standing. The therapist adequately assists the movement.	
4	The patient is instructed to place both arms on the ground and to move into a 4-Foot-Position. The therapist adequately assists the movement.	
5	The patient is instructed to sit down on one side. The therapist adequately assists the movement.	
6	The patient is asked to lie on the mat. The therapist adequately assists the movement.	
Up		
7	The patient is instructed to extend the elbow and trunk and to sit on the side. The therapist adequately assists the movement.	
8	The patient is instructed to move into a 4-Foot-Position. The therapist adequately assists the movement.	
9	The patient is instructed to move into a knee-standing position. The therapist adequately assists the movement.	
10	The patient is instructed to place one foot forward. The therapist supports the weaker hip and the movement.	
11	The patient is instructed to place the stronger arm on the bench and to sit on the bench. The therapist adequately assists the movement.	

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Queen Margaret University EDINBURGH

Case report form: Procedure specific checklist vestibular rehabilitation

Date:

Participant ID: ☐ **Rater:** ☐

Instructions:

Two points will be awarded to a correct performance, one point will be given if the performance is performed with minor mistakes and zero points will be given if the item is performed with major mistakes or omitted

Step	Description of steps	Scores (2,1 or 0)
Dix Hallpike manoeuvre		
Pre	The patient is adequately informed and prepared for the procedure.	
1	The patient rests in an upright-seated position and the clinician stands next to the patient.	
2	The clinician rotates and supports the patient's head 45° to the side to be tested.	
3	The patient is quickly moved to a supine lying position with the ear to be tested pointing downwards. Furthermore, the head of the patient is slightly extended (~20° below horizontal). The clinician supports the head and observes the patient's eyes for a potential nystagmus The clinician asks for symptoms of vertigo.	
4	When nystagmus and vertigo have subsided the patient's body is brought up slowly to a sitting position. The head is still held in a 45° rotation to side to be tested and the patient is again observed for vertigo and nystagmus.	
5	The manoeuvre is repeated with the head rotated to the other side.	
Canalith repositioning technique		
Pre	The patient is adequately informed and prepared for the procedure.	
1	Patients rests in an upright-seated position and the clinician stands next to the patient. The patient's head is rotated 45° towards the affected side.	
2	The patient is positioned in the Dix Hallpike position. Head rotated towards the affected side. The patient rests in this position until symptoms subside.	

3	The patient's head is turned 90° towards the not affected side. The patient rests until symptoms subside.	
4	The patient is rolled on his/ her side. The head is turned in direction of the floor. The not affected side is close to the floor.	
5	The clinician supports the patient to move into an upright-seated position.	
6	The clinician provides post procedure instructions	
Liberatory manoeuvre		
Pre	The patient is adequately informed and prepared for the procedure.	
1	The patient is instructed to sit sideways on the examination table. The patient's head is rotated 45° degrees towards the not affected side.	
2	The patient is quickly moved into a side-lying position on the not affected side. The clinician reassures a head rotation of 45° towards the not affected side. The patient rests 2 to 3 minutes in this position.	
3	The clinician rapidly moves the patient with a 180° degrees' movement into a side-lying position on the other side (without a break at the sitting position). The patient's head position is maintained throughout the movement.	
4	If no nystagmus or vertigo is elicited in this position the clinician shakes the head of the patient once or twice with a small amplitude.	
5	The patient is slowly moved into a sitting position.	
6	The clinician provides post procedure instructions.	

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EDINBURGH

Case report form: Assessment self-reported confidence

Date:

Participant ID: ☐ **Rater:** ☐

Instructions:

Please answer the following three questions.

How confident are you performing the procedure "transfer to the ground"?	Very confident				not at all confident
	0	0	0	0	0
How comfortable are you independently planning the procedure "transfer to the ground"?	Very confident				not at all confident
	0	0	0	0	0
How confident are you that you would not avoid a "transfer to the ground" procedure in the future?	Very confident				not at all confident
	0	0	0	0	0

Case report form: Assessment self-reported confidence

Date:

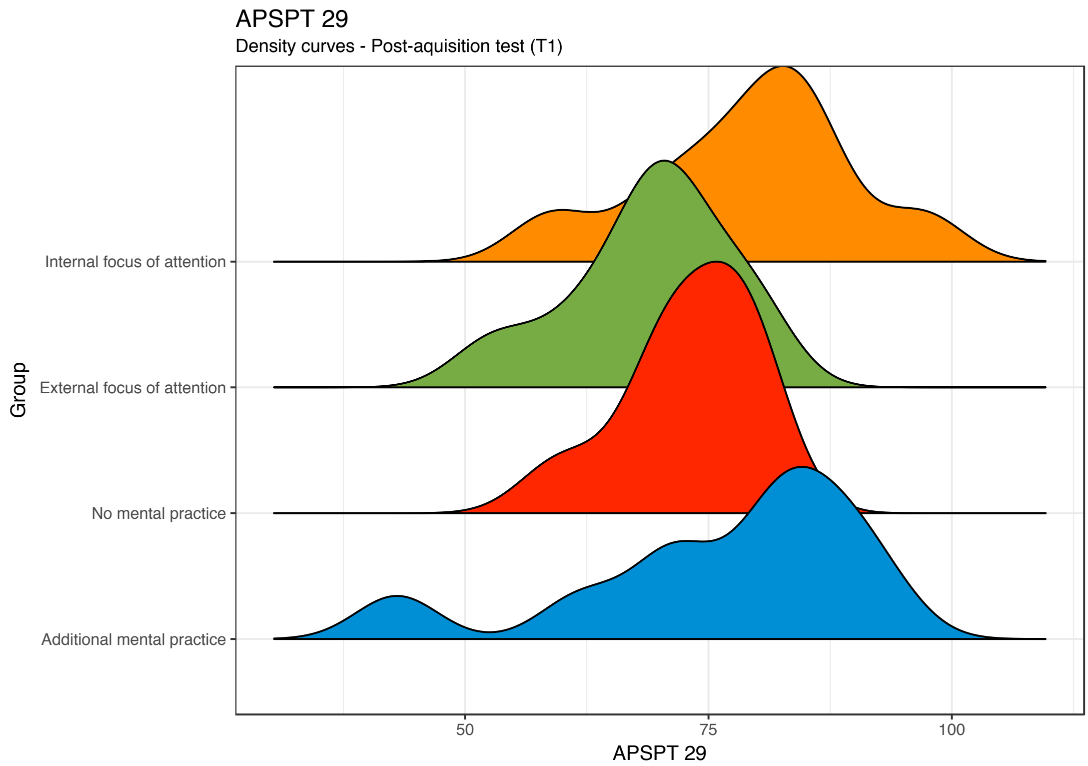
Participant ID: ☐ **Rater:** ☐

Instructions:

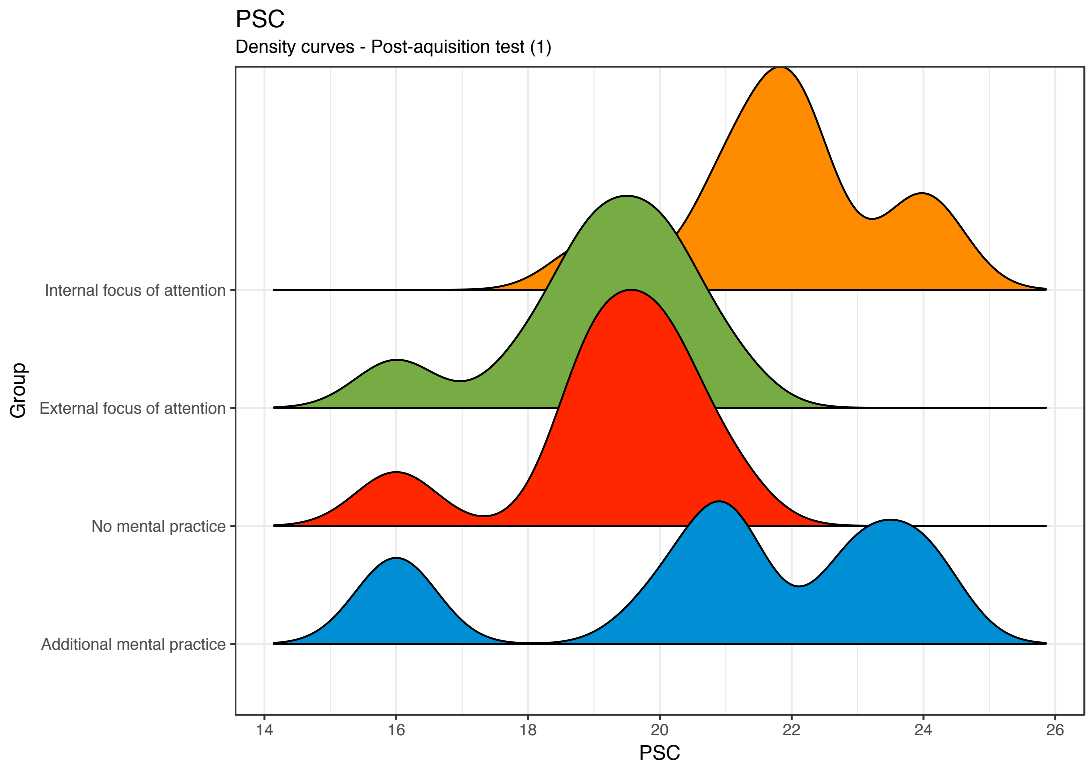
Please answer the following three questions.

How confident are you performing the “vestibular rehabilitation” procedure?	Very confident				not at all confident
	0	0	0	0	0
How comfortable are you independently planning the “vestibular rehabilitation” procedure?	Very confident				not at all confident
	0	0	0	0	0
How confident are you that you would not avoid a “vestibular rehabilitation” procedure in the future?	Very confident				not at all confident
	0	0	0	0	0

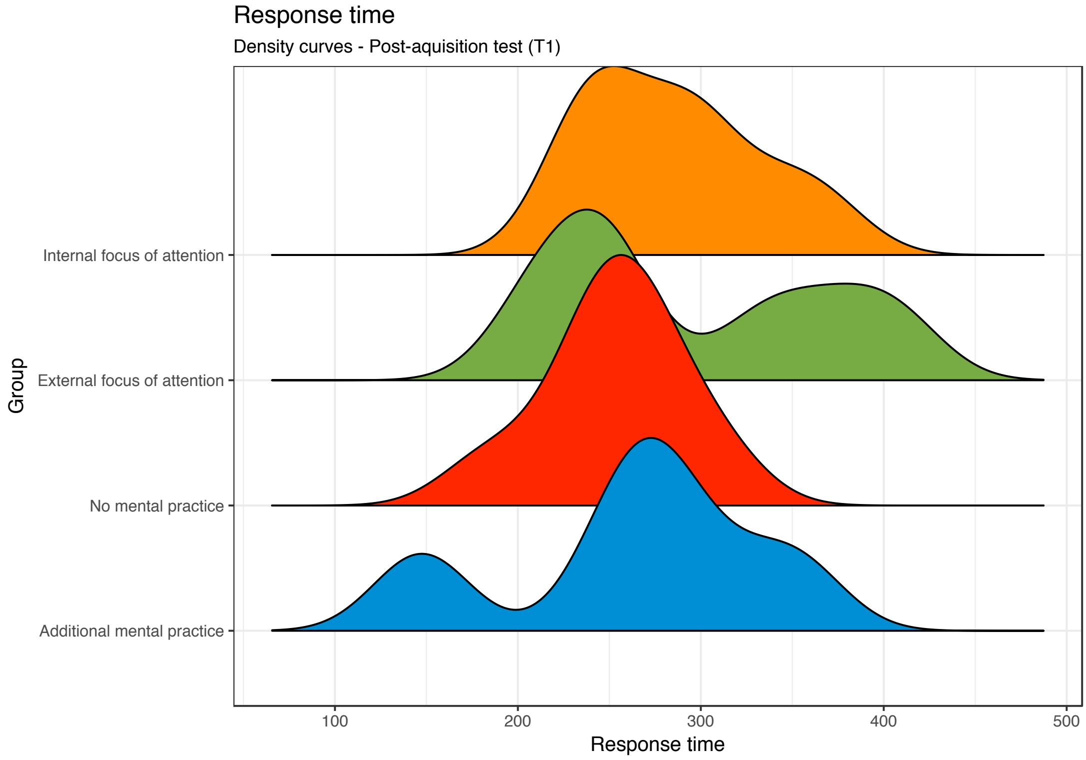
APSPT 29


APSPT 29
Density curves - Post-aquisition test (T1)
Internal focus of attention
External focus of attention
No mental practice
Additional mental practice
Group
50
75
100
APSPT 29

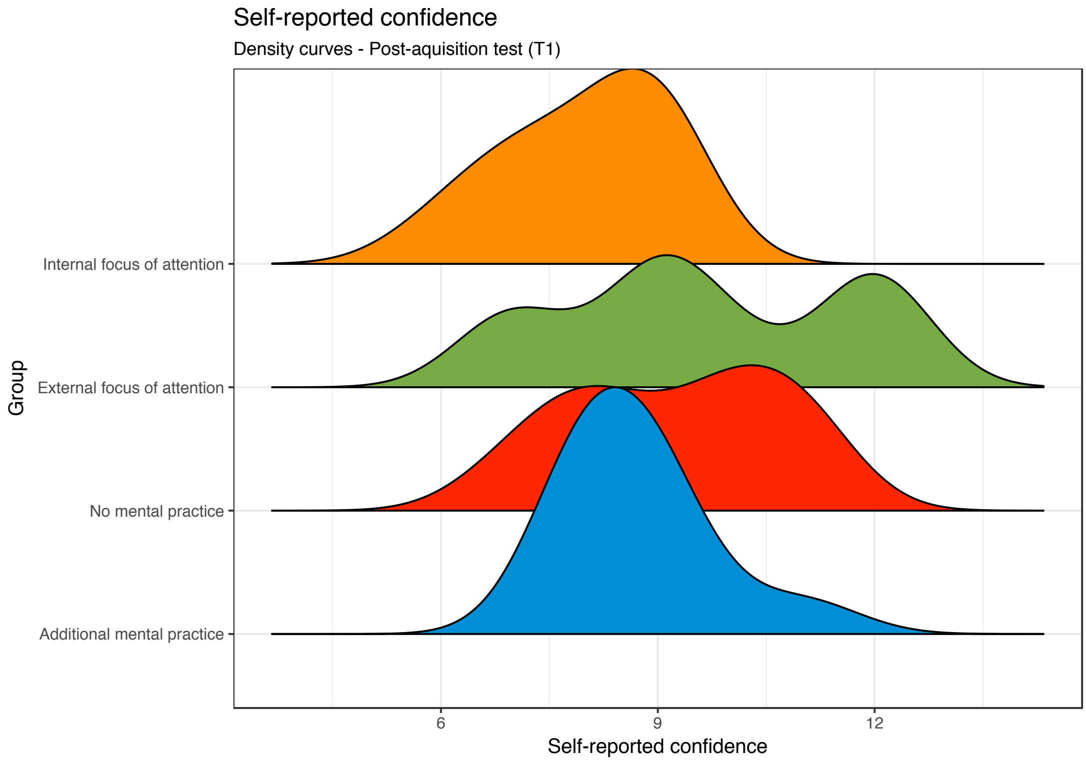
PSC


PSC
Density curves - Post-aquisition test (1)
Internal focus of attention
External focus of attention
No mental practice
Additional mental practice
Group
14
16
18
20
22
24
26
PSC

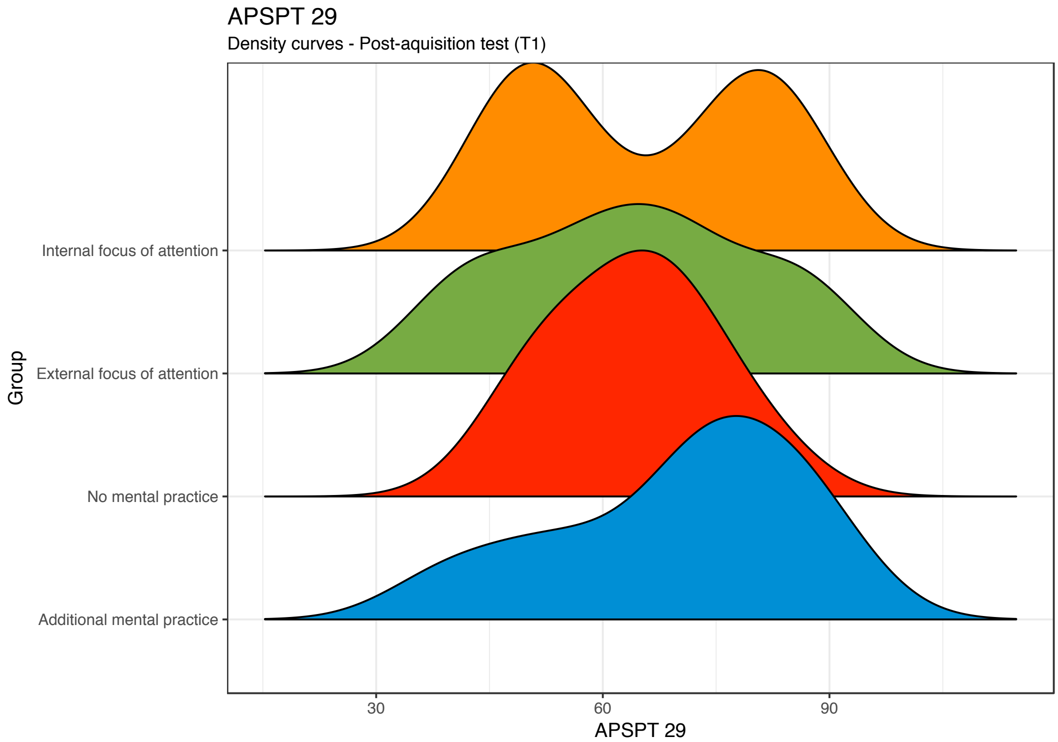
Response time



Self-reported confidence

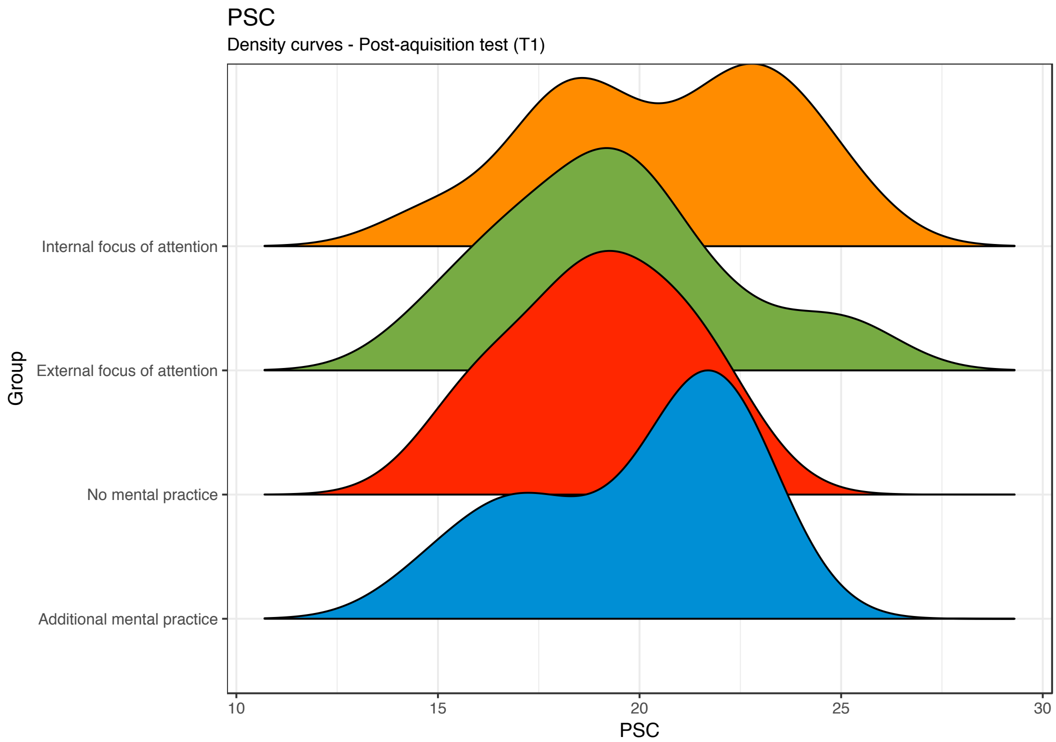


APSPT 29



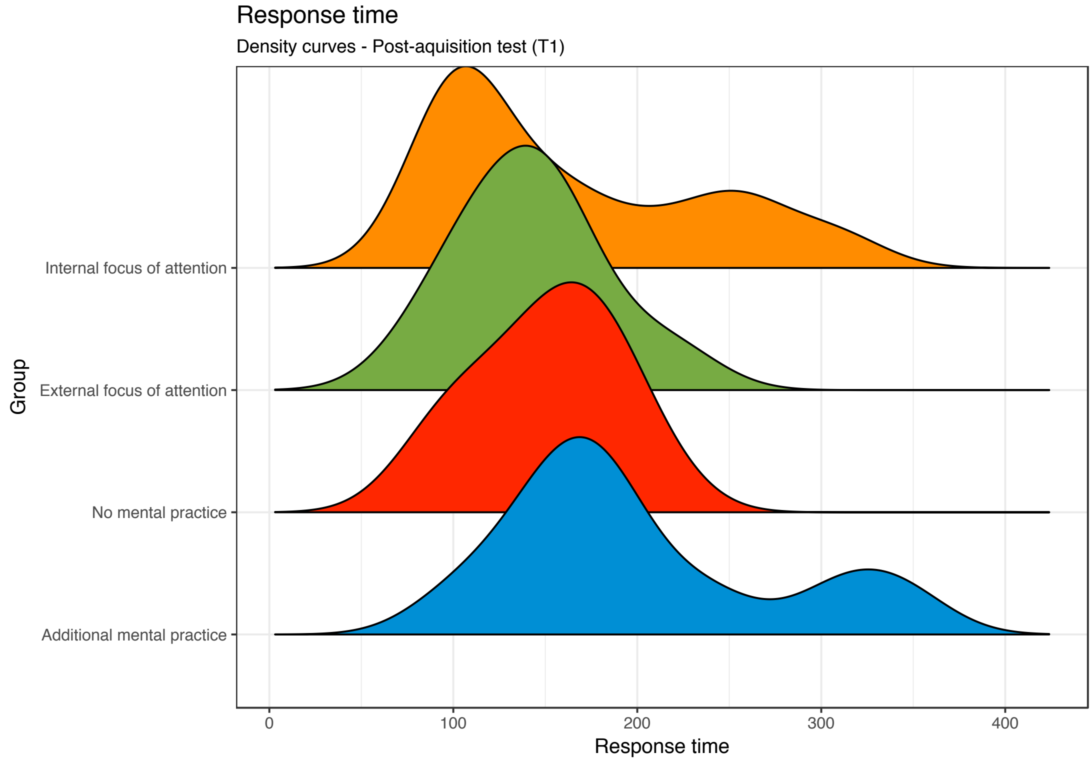
APSPT 29
Density curves - Post-aquisition test (T1)
Internal focus of attention
External focus of attention
No mental practice
Additional mental practice
Group
30
60
90
APSPT 29

PSC

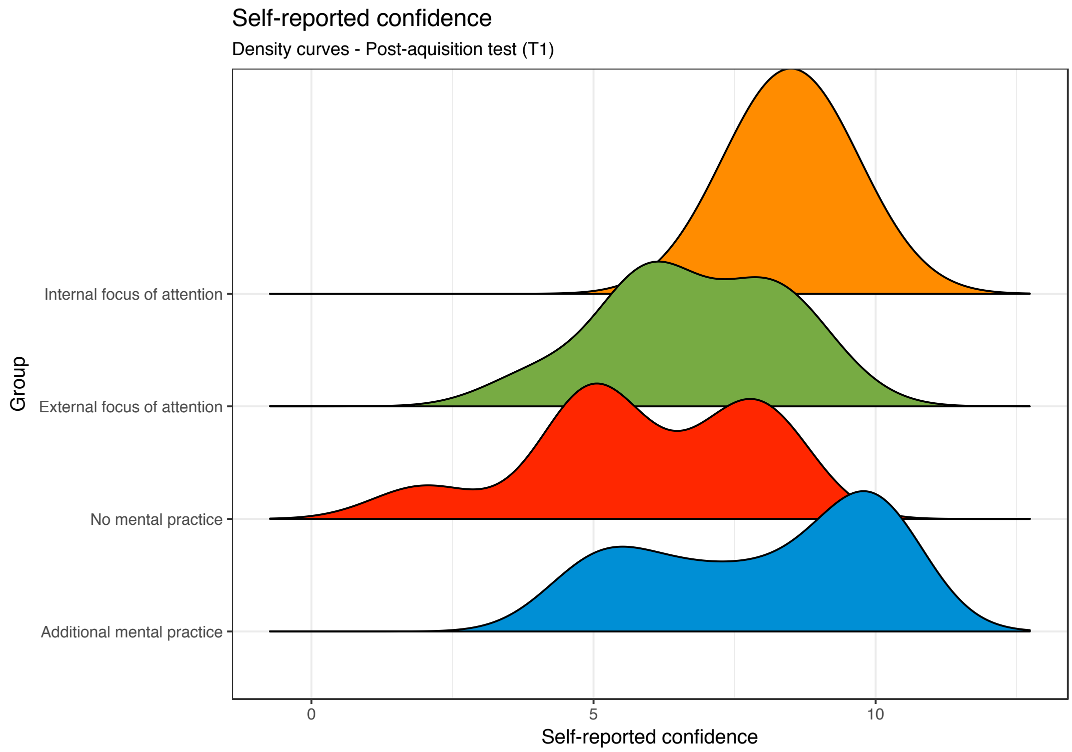


PSC
Density curves - Post-aquisition test (T1)
Internal focus of attention
External focus of attention
No mental practice
Additional mental practice
Group
10
15
20
25
30
PSC

Response time



Self-reported confidence



Appendix xiii Publications

Appendix xiv Educational scripts

Transfer task procedure

- MP
- EFA
- IFA

Vestibular rehabilitation task procedure

- MP
- EFA
- IFA

NB. For the nMP groups the same scripts as in the MP group were used.

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RESEARCH ARTICLE Open Access

A systematic review and meta-analysis of selected motor learning principles in physiotherapy and medical education

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Abstract

Background: Learning of procedural skills is an essential component in the education of future health professionals. There is little evidence on how procedural skills are best learnt and practiced in education. There is a need for educators to know what specific interventions could be used to increase learning of these skills. However, there is growing evidence from rehabilitation science, sport science and psychology that learning can be promoted with the application of motor learning principles. The aim of this review was to systematically evaluate the evidence for selected motor learning principles in physiotherapy and medical education. The selected principles were: whole or part practice, random or blocked practice, mental or no additional mental practice and terminal or concurrent feedback.

Methods: CINAHL, Cochrane Central, Embase, Eric and Medline were systematically searched for eligible studies using pre-defined keywords. Included studies were evaluated on their risk of bias with the Cochrane Collaboration's risk of bias tool.

Results: The search resulted in 740 records, following screening for relevance 15 randomised controlled trials including 695 participants were included in this systematic review. Most procedural skills in this review related to surgical procedures. Mental practice significantly improved performance on a post-acquisition test (SMD: 0.43, 95 % CI 0.01 to 0.85). Terminal feedback significantly improved learning on a transfer test (SMD: 0.94, 95 % CI 0.18 to 1.70). There were indications that whole practice had some advantages over part practice and random practice was superior to blocked practice on post-acquisition tests. All studies were evaluated as having a high risk of bias. Next to a possible performance bias in all included studies the method of sequence generation was often poorly reported.

Conclusions: There is some evidence to recommend the use of mental practice for procedural learning in medical education. There is limited evidence to conclude that terminal feedback is more effective than concurrent feedback on a transfer test. For the remaining parameters that were reviewed there was insufficient evidence to make definitive recommendations.

Keywords: Procedural skills, Clinical skills, Motor learning, Practice schedule, Mental practice, Feedback

Background

Learning of procedural skills is an essential component in in the education of future medical and physiotherapy professionals [1]. Teaching of procedural skills is traditionally based in the field of surgical education, but has moved in the last decades to almost every discipline in medicine and health professions education (HPE) [2]. Procedural skills are taught in many healthcare areas, for example in nursing education (e.g. intubation) and physiotherapy education (e.g. joint mobilisation). Procedural skills in HPE are highly context specific and learners need to adapt to various conditions [3]. Procedural skills in the context of HPE are often classified under the umbrella term "clinical skills" [4]. However, some authors refer to "psychomotor tasks" [5] where others also include tasks such as communication skills and treatment skills under "procedural skills".

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Training in HPE is expensive and therefore training should be effective [6]. To improve effectiveness, educators need to know what specific educational interventions could be used to enhance learning of these procedural skills. For this review, we defined procedural skills as "a motor skill involving a series of discrete responses each of which must be performed at the appropriate time in the appropriate sequence" [7]. A procedure can serve different purposes (e.g. it may be a diagnostic or therapeutic procedure). Procedures can be simple tasks with only a few parts or they can involve complex sequences of multiple activities that are linked together. Each procedure requires acquisition of unique motor skills. Because of this similarity we are using the terms procedural skills and motor skills interchangeably in this review. We appraised learning of procedures from the study of motor learning, which is the study of the acquisition of motor skills or the performance improvement of learned or highly practiced motor skills [8].

Learning is defined as: "A change in the capability of a person to perform a skill that must be inferred from a relatively permanent improvement in performance as a result of practice"[8, p. 257]. However, this changed capability in motor learning is not directly measurable, because the changes responsible for motor learning are complex processes within the central nervous system. Therefore, change can be inferred by sustained improved performance, but measurement with standardised educational tests is difficult.

Brydges and colleagues [9] argue that programmes in HPE concentrate efforts to improve aspects of education such as evaluation methods. In contrast, very little consideration is given to and there is little evidence on how procedural skills are best taught and practiced in education. There is however, growing evidence from rehabilitation science, sport science and psychology that motor learning can be promoted with the application of motor learning principles (e.g. [10–12]). Wulf et al. [13] proposed that motor-learning principles should be applied to the field of HPE. They argue that procedural skills are an essential component in many curricula. Furthermore, major changes on how procedures are learned have recently been proposed (among others a shift away from traditional approaches of procedural skill learning in HPE such as the Halstedian "see one, do one, teach one" training and involvement of new technologies during procedural learning), and recent evidence questions some traditional assumptions regarding skills learning (e.g. the effectiveness of different practice schedules) [13]. In addition, the way instructions and feedback are given is noted to be not in accordance with research evidence [12]. This emerging interest in how procedural skills are taught formed the basis for this review.

In considering the learning of procedural skills, there are a number of clearly defined parameters within the sports science literature. These mostly look at how to structure practice; how and when to provide feedback and how and when to integrate mental practice alongside physical practice [8]. In undertaking this systematic review, the authors reviewed the literature in relation to motor skill acquisition principles that had some published evidence and that were deemed relevant to HPE. Motor learning texts [8, 14] were searched for eligible principles to include. Firstly, selection of principles was based on available evidence in HPE (i.e. at least one published RCT). Secondly, it should be possible to apply the principle without considerable technical equipment. Within this review four motor learning principles were deemed relevant:

- Part practice or whole practice
- Random practice or blocked practice
- Mental practice
- Augmented feedback (terminal feedback or concurrent feedback)

For clarity, a brief definition of each principle is provided below and a practical application of the principles is presented as an Additional file 1.

Part practice or whole practice

A procedural skill can be trained with different practice schedules. Learning a procedure in a part practice condition requires breaking this procedure into several fundamental movement segments. After mastering the isolated parts the learner proceeds to practice the parts together. In whole practice the entire procedure is taught in a serial order and as a whole entity [9].

Random practice or blocked practice

In random practice, multiple components of a procedural skill are practiced in a single session in a random order. Conversely, blocked practice, requires skills to be practiced in closed blocks and progression to the next skill in the block occurs after a predefined amount of practice. Organisation of the practice schedule into random practice may increase the level of difficulty during skill learning and can therefore have negative effects on the performance of the procedure on post-acquisition tests (i.e. a test immediately after an intervention) but may increase performance on retention and transfer tests [15]. It was hypothesised that the increased performance may be caused by more intensive motor planning operations during random practice conditions, which can lead to better memory retrieval on retention and transfer tests [16].

Mental practice
Mental practice is a method for learning a procedure without actually physically performing it. Mental practice relates to mental rehearsal in this review. This doesn't cover other practice conditions such as relaxation or meditation exercises. Mental practice may involve exercises such as thinking about the procedure and its parts but mental practice may also include different imagery techniques (with the purpose to maximise equivalence with physical practice, e.g. instruction mode or position of the learner) [17].

Augmented Feedback (terminal feedback or concurrent feedback)
Augmented feedback is defined as "information about a performance that supplements sensory feedback and comes from a source external to the performer" ([8], p. 344). In educational settings the external source might be an educator. But augmented feedback can also be generated with a computer. An important question in HPE with controversial opinions is the timing of the augmented feedback [8]. When concurrent feedback is used the learner receives augmented feedback during the movement. In contrast terminal feedback is provided after the procedure is completed.

Learning versus performance
Several possible methods exist to evaluate the performance of a learner. Firstly, "post-acquisition tests" measure performance immediately at the end of an intervention designed to improve learning. This method is valid to measure a change in performance, but because of the immediacy of testing, caution is required in interpreting whether learning has occurred as the resultant performance reflects a potentially temporary situation and should not be associated with a relatively permanent change associated with learning. Rather than testing learning immediately after the teaching and practicing of a new skill, researchers advocate undertaking a "retention test" during which time a rest period (usually a few hours or days) is inserted between the last practice trial and the retention test. The idea of this resting period is that non-permanent effects of the intervention are eliminated and only the permanent changes, which might be indicative of learning are measured. Lastly, researcher may use a "transfer test". During transfer tests, the ability of the learner to adapt the newly learnt procedural skill to a different situation is tested (e.g. a similar task is practiced in a novel situation under time constraints), often at a time-point distant to the skill acquisition phase. The assumption behind transfer tests is that the adaptability of a learner to a variety of circumstances increases with the degree of learning [8]. This implies that in the situation when learning has not occurred, but there has been a temporary improvement in performance on a post-acquisition test an individual may be unable or will only have limited ability to adapt a procedure to a new situation. In contrast a skilled person, who has acquired genuine learning will be able to adapt the procedural skill to new demands.

Aim
The aim of this review was to evaluate the evidence for the effectiveness of using motor learning principles to promote learning of procedural skills in physiotherapy and medical education.

Methods
Selection of studies
The following criteria were used to include or exclude studies:

Inclusion criteria
Population
We were interested in studies that included students in medical and physiotherapy education. This included undergraduate and postgraduate students.

Intervention
The intervention had to use at least one of the four motor learning principles identified above with the aim of improving the learning of procedural skills.

Outcomes
The primary outcome of this review was learning of a procedural skill measured by performance of the procedure. Two different kinds of performance tests for measuring outcome were deemed eligible for this review.

1. The first were procedural specific checklists and the second were global rating scales. Procedural specific checklists identify important parts of a procedure and every task is usually scored on a dichotomous scale. Global rating scales are designed with a range of response options and can be used for more than one procedure. Both types of measurement instruments are frequently used in education research and are valid outcome measures to evaluate the performance of a procedure [18]. Norcini [19] reported a strong correlation between both types of measurements.
2. The second outcome of this systematic review was movement duration. Especially, in surgery movement duration is an important measure for procedure performance [20]. Only studies with at least one of these outcomes were included.

Outcomes taken either during post-acquisition, retention or transfer tests were considered appropriate for this review.

Design

Randomised controlled studies were included.

Search methods for identification of studies

The following electronic databases were systematically searched for eligible studies: CINAHL, Cochrane CENTRAL, EMBASE, ERIC and Medline. There was no limit on recency of publication and language of publication. The search string is presented in Table 1. All retrieved papers were imported in an electronic literature management system. In a first step duplicates were removed. In a second step one author (MS) screened titles and abstracts of the remaining records and excluded all irrelevant papers. Lastly, all remaining records were read as full-text articles by two reviewers (SE and MS) and included into the analysis if appropriate. Furthermore, the reference lists of the included articles were hand-checked for additional relevant articles. Two reviewers (SE and MS) independently performed the data extraction. Disagreements between the reviewers (SE and MS) were solved by discussion.

Measures of treatment effect and analysis

For all continuous outcomes means and standard deviations for all groups and all measures were extracted (this included baseline measures, post-acquisition -tests, retention tests and transfer tests). For continuous outcomes a pooled estimate of the standardized mean difference (SMD) with corresponding 95 % confidence intervals was estimated. Effect sizes were interpreted as described by Cohen (i.e. 0.2 represents a small effect, 0.5 a moderate effect and 0.8 a large effect) [21]. Statistical heterogeneity was evaluated with the I^2 statistic [22]. With the help of I^2 statistic it is possible to classify the proportion of effect estimates that can be attributed to heterogeneity between studies rather than sampling error [23]. I^2 was classified accordingly to the guidelines presented in the Cochrane handbook for systematic reviews of interventions [24] (i.e.: 0 to 40 %: might not be important, 30 to 60 %: may represent moderate heterogeneity, 50 to 90 %: may represent substantial heterogeneity, 75 to 100 %: considerable heterogeneity).

Assessment of risk of bias in included studies

Two reviewers independently evaluated the risk of bias of the included studies with the Cochrane Collaboration's risk of bias tool [25]. After extraction of necessary data several sources of bias were evaluated (i.e. random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessor, incomplete outcome data and selective reporting). The categories blinding of outcome assessor and incomplete outcome data were separately evaluated for the outcomes movement duration and procedure performance. Studies were classified as having a high risk of bias when at least one item was rated as high risk. An unclear risk of bias was assigned when at least one item was classified as unclear risk. And a low risk of bias was assigned when all items were rated as having a low risk.

Results

Results of the search

The search on electronic databases identified 874 potential records. It was possible to remove 134 duplicates. After screening of 740 titles and abstracts 686 records were excluded. The majority of records were excluded because of their intervention, a further 12 records were excluded due to study design and finally 4 records were excluded due to their population.

The remaining 54 full-text articles were evaluated and 39 were excluded due to various reasons: Nine studies were reviews of primary studies [2, 13, 26–32]. Three studies recruited or described participants not matching the inclusion criteria [33–35]. Sixteen studies compared interventions not relevant for this review [36–51]. Ten studies used a design that was not eligible for this review [52–60]. One study trained a procedure that was not eligible for this

Table 1 Search strategy

Population	Intervention	Outcome
medical education OR education, medical [Mesh] OR physiotherapy education OR physical therapy education OR health professions education OR healthcare education	whole practice OR part practice OR random practice OR blocked practice OR whole task OR part task OR random task OR blocked task OR practice schedule OR practice distribution OR mental imagery OR mental practice OR mental rehearsal OR augmented feedback OR knowledge of results OR knowledge of performance OR terminal feedback OR concurrent feedback OR focus of attention OR external focus OR internal focus OR motor learning OR procedural learning OR teaching method OR learning method	performance OR learning OR proficien* OR mastery OR competenc* OR skills OR skill OR procedur* OR assessment OR comparative OR compare OR comparison OR measure* OR evaluat* OR educational measurement

* indicates a truncation search

review [61]. The remaining 15 studies were included for analysis in this review. An overview of the study flow during the selection process is presented in Fig. 1.

Included studies

It was possible to include 15 studies with a total of 695 participants. All included studies were randomised controlled trials. In three studies part practice was compared against whole practice [9, 62, 63]. All three studies were performed in medical education. Because Brydges et al. [9] and Dubrowski et al. [62] included 3 arms (1st arm whole practice, 2nd arm part practice (blocked), 3rd arm part practice (random)) in their studies, they could also compare random practice against blocked practice. The influence of mental practice on procedural learning was evaluated by eight studies in the field of medical education [64–71]. Lastly, 4 studies evaluated whether terminal feedback or concurrent feedback was more beneficial for learning a procedure [72–75]. The first study [72] analysed the learning in undergraduate physiotherapy students. The last three studies were performed in medical education. A summary of the key characteristics of the 15 included studies is presented in Table 2.

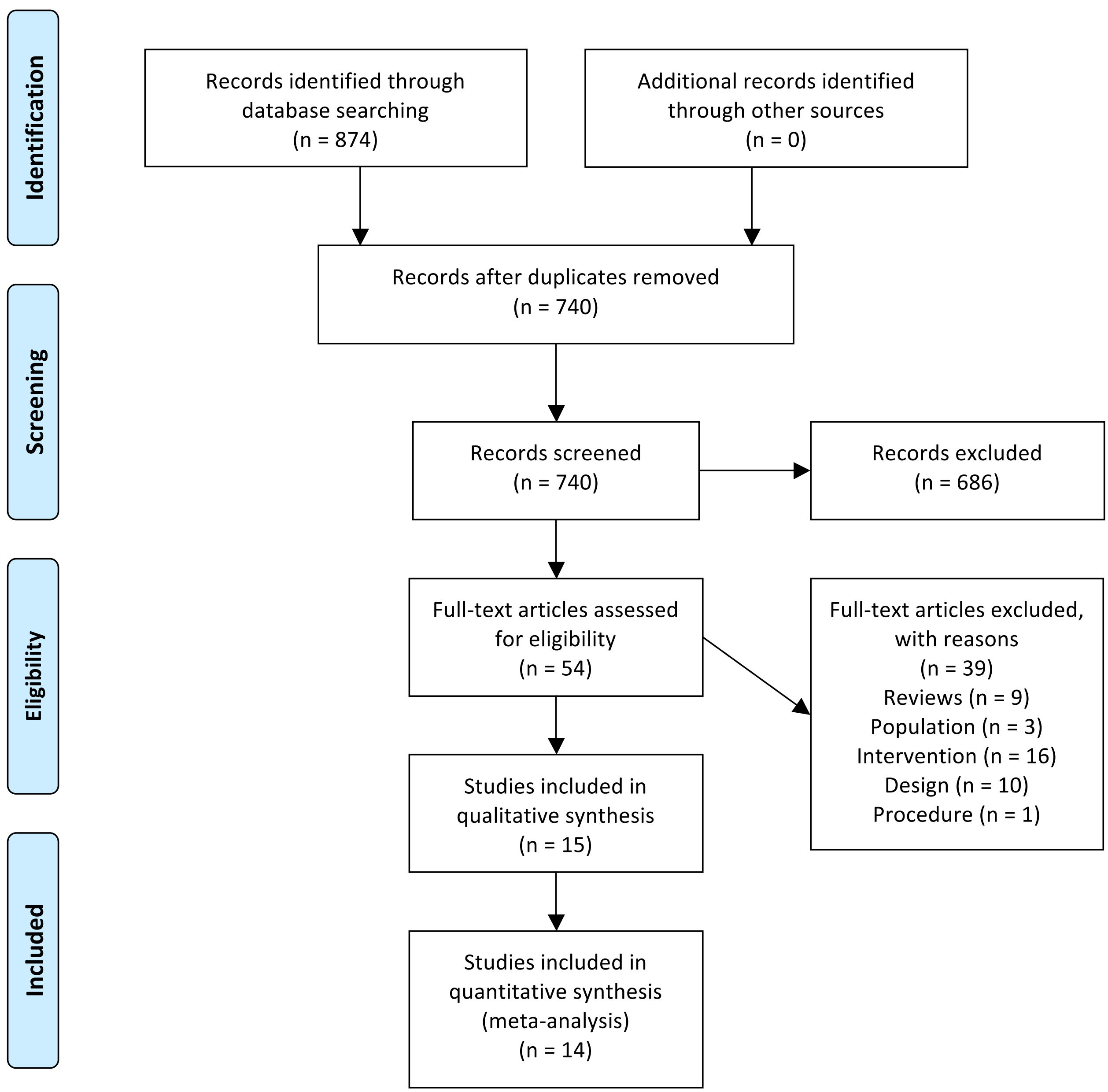

Fig. 1 Study flow

Table 2 Characteristics of included studies

Motor learning principle	Study	Design/ Setting	Population	Experience	Procedure	Educational intervention	Outcome measurement	Endpoints	Main findings
Part task practice-Whole task practice	Brydges et al. [9]	RCT (3 arms)/ Canada	*N* = 18 post-graduate surgical residents (1st year)	Unclear experience	Orthopaedic surgical task (bone-plating task on artificial radial bones, with five separate skills)	Group 1: Whole task practice	Motion analysis system:	Pre-test	Post-acquisition-test:
						Group 2: Part task practice (random)	a) Number of hand movements	Post-acquisition test (5 min after training)	PT: Similar performance between groups
						Group 3: Part task practice (blocked)	b) Total time on task Videotape (expert evaluation):	Transfer test (1 week after the acquisition phase on an artificial radius)	MD: In favour of part practice (not significant)
							a) Global rating scale (operative performance)		Transfer test:
							b) 15-item checklist (operation-specific procedures)		PT: Infavour of part practice (not significant)
							c) Final product analysis		MD: In favour of part practice (not significant)
	Dubrowski et al. [62]	RCT (3 arms)/ Canada	*N* = 28 medical students (1st and 2nd year),	Novice learners	Orthopaedic surgical task (bone plating task on artificial ulna bones, with five separate skills)	Group 1: Whole task practice ("functional-order-practice") (3× 20 min sessions)	a) Checklist (operation-specific measurements)	Pre-test	Post-acquisition-test:
							b) Final product analysis	Post-acquisition test (immediately after acquisition phase)	PT: In favour of whole practice (significant)
						Group 2: Part practice (random) (3× 20 min. sessions)	c) Global rating scale (general operative performance)		
						Group 3: Part practice (blocked) (5× 12 min. sessions)	d) Duration of the drilling skill	Retention test (after 30 min rest period)	
						All participants practiced each skill 3 times for 2 min and 10 sec			

Table 2 Characteristics of included studies *(Continued)*

	Willaert et al. [63]	RCT/UK	*N* = 20 junior medical residents (surgery, radiology and cardiology)	Prior experience as an operator but not with this procedure	Carotid stenting procedure (virtual reality simulation)	Group 1: Part task rehearsal; 30 min of repeated catheterisations	a) Simulator derived dexterity metrics (procedure time, fluoroscopy time, contrast volume and number of roadmaps)	Post-acquisition test immediately after the training on a “real” patient	Post-acquisition-test:
						Group 2: Whole task rehearsal (*N* = 10); one full task rehearsal (~30 min)	b) Video recordings of hand movements (evaluated with a GRS and a PSRS)		PT: Similar performance between groups
							c) Non Technical Skills for Surgeons Rating Scale		MD: Similar performance between groups
							d) Self-assessment		
Random practice-Blocked practice	Brydges et al. [9]	See above	See above	See above	See above	See above	See above	Pre-test	Post-acquisition-test:
								Post-acquisition test (5 min after training)	PT: In favour of random practice (not significant)
								Transfer test (1 week after the acquisition phase on an artificial radius)	MD: In favour of random practice (not significant)
									Transfer test:
									PT: In favour of blocked practice (not significant)
									MD: In favour of random practice (not significant)

Table 2 Characteristics of included studies *(Continued)*

	Dubrowski et al. [62]	See above	See above	See above	See above	See above	See above	Pre-test	Post-acquisition-test:
								Post-acquisition test (immediately after acquisition phase)	PT: In favour of random practice (not significant)
								Retention test (after 30 min rest period)	
Mental practice	Arora et al. [64]	RCT/UK	*N* = 18 (surgeons)	Novices to laparoscopic surgery	Laparoscopic chole-cystectomies (simulation)	Group 1: Had an additional mental practice session before the simulation (30 min)	a) GRS of technical skills	Pre-test	Post-acquisition-test:
						Group 2: Had no additional training	b) Mental Imagery Questionnaire	Post-acquisition test	PT: In favour of mental practice (significant)
								Learning curve (all 5 practice sessions were measured)	
	Bathalon et al. [65]	RCT (3 arms)/ Canada	*N* = 44 medical students (1st year)	Novices	Cricothyrotomy (simulation)	Group 1: Kinesiology practice (cognitive task analysis). The procedure was divided in 8 specific steps. All steps were discussed and practiced separately	OSCE examination: a) Knowledge of needed steps	Retention test (2 weeks after the teaching event)	Retention test: MD: In favour of no mental practice (not significant)
						Group 2: Kinesiology and mental imagery. Same practice as group 1. With additional 5 min of mental imagery	b) Time and fluidity of intervention		

Table 2 Characteristics of included studies *(Continued)*

					Group 3: Standard educational ATLS approach			
Geoffrion et al. [66]	Multi-centre RCT/8 centres across Canada and the USA	*N* = 50 junior gynaecology residents	All participants were at the start of their learning curve	Vaginal hysterectomies	Group 1: Mental Practice. The MP script enumerated the procedure steps based on a reference textbook. The participants performed the MP with an expert educator. MP was continued individually until the participant felt comfortable with the procedure. Group 2: Participants were encouraged to read a textbook describing the procedure.	a) GRS of surgical skill b) Procedure-specific score c) Self-assessment (GRS) d) Self-confidence e) Time in operating theatre f) Attending surgeons evaluations (e.g. blood loss and complications)	Pre-test Post-acquisition test (immediately after the intervention)	Post-acquisition-test: PT: In favour of mental practice (non significant) MD: In favour of mental practice (not significant)
Jungmann et al. [67]	RCT/Germany	*N* = 40 medical students	Novice learners	Laparoscopic exercises:	All participants followed 2 sessions on a simulator with three tasks.	Performance measures:	Pre-test (parameters of the 1st training session)	Post-acquisition-test:
				a) Grasping movements	Between the 2 sessions:	a) Time		
				b) Tissue manipulation	Group 1: Additional mental practice (at least 4 times and not less than 3 min)	b) Tip trajectory		
				c) Surgeons' Knot	Group 2: No additional training	c) Time of the instrument collision Visual-spatial ability: a) Cube test	Post-acquisition test (parameters of the 2nd training session)	MD: In favour of no mental practice (not significant)

Table 2 Characteristics of included studies *(Continued)*

Komesu et al. [68]	Multi-centre RCT/6 academic centres in the USA	*N* = 68 gynaecology residents	Some prior experience with the procedure	Cystoscopy	Group 1: Mental practice 24-48 h prior to a scheduled cystoscopy. Session lasted < 20 min Group 2: Students were encouraged to read a standard text 24-48 h prior to a scheduled cystoscopy.	a) Global Scale of Operative Performance b) Time required for cystoscopy c) Competence to perform the procedure d) Preparedness for the procedure	1st Post-acquisition test (Evaluation of the 1st procedure) 2nd Post-acquisition test (Evaluation of the 2nd procedure)	Post-acquisition-test: PT: In favour for mental practice (significant) MD: In favour of no mental practice (not significant)
Rakestraw et al. [69]	RCT/USA	*N* = 160 medical students (2nd year)	Novice learners	Pelvic examination	Group 1 (control group): 1 student practiced the task and two students observed the performance Group 2: Mental practice before the task (pre-motor). Group 3: Mental practice after the task (post-motor) Group 4: Mental practice before and after the task.	Knowledge of attainment a) Memory list of relevant steps b) Patient record Performance measures: a) Behavioural checklist	1st post-acquisition test (after practice on models) Retention test (immediately before the evaluation on a simulated patients) Transfer test (simulated -patients)	Study not included into the meta-analysis
Sanders et al. [70]	RCT (3arms)/USA	*N* = 65 medical students (2nd year)	Unclear experience	Cutting and suturing a pig's foots	Group 1: 3 sessions of physical practice Group 2: 2 sessions of physical practice and 1 session of mental practice (relaxation exercises and imagery exercises)	a) 7-item GRS b) Surgical skills attitude questionnaire (Confidence)	Post-acquisition-test (During the 1st training session) Transfer test (10 days after the last session)	Post-acquisition-test: PT: In favour of mental practice (not significant) Transfer test:

Table 2 Characteristics of included studies *(Continued)*

						Group 3: 1 session of physical practice and 2 sessions of mental practice (relaxation exercises and imagery Tr test: exercises)			PT: In favour of no mental practice (not significant)
	Sanders et al. [71]	RCT/USA	$N = 64$ medical students (2nd year)	Unclear experience	Cutting and suturing a pig's foot	Group 1: Mental practice for ~30 min (1st part relaxation exercises and 2nd part imagery exercises) (2 sessions)	Surgical performance: a) 15 item checklist (surgical behaviour) b) 6 specific rating scales	Pre-test (confounding)	Post-acquisition-test:
						Group 2: Textbook study for 30 min (using a verbal method) (2 sessions)	Measurement of confounding:	Post-acquisition test (after the 1st intervention period)	PT: In favour of no mental practice (not significant)
						Afterwards: All participants received 1 h practice under supervision (together)	a) Self-confidence b) Prior learning c) Anxiety d) Visual-spatial ability	1st retention test (after the 1 h practice session) 2nd retention test (10 days after the last intervention)	Transfer test: PT: In favour of mental practice (not significant)
Terminal Feedback-Concurrent Feedback	Chang et al. [72]	RCT (3arms)/Taiwan	$N = 36$ undergraduate physical therapist students	Limited exposure to peripheral joint mobilisa-tion	Joint mobilization (simulation)	Group 1: Received concurrent graphical feedback on their performance during three 25 trials blocks	Accuracy of performance: a) Deviation of the grading force	Pre-test Acquisition phase test	Post-acquisition-test: PT: In favour of terminal feedback (not significant)
						Group 2: Received terminal feedback on their performance after each trial block		Post-acquisition test (10 min after the acquisition phase)	Retention test:

Table 2 Characteristics of included studies *(Continued)*

					Group 3: Received no feedback The skill acquisition phase lasted ~40 min for all groups		Retention test (5 days after the acquisition phase)	PT: In favour of concurrent feedback (not significant)
Gofton et al. [73]	RCT (3 arms)/Canada	*N* = 45 surgical residents (1st or 2nd year) or senior medical students	Some prior experience with the procedure	Acetabular cup placement (simulation)	Group 1: Conventional training	Performance measures:	Pre-test	Post-acquisition-test:
					Group 2: Received concurrent feedback during each trial	a) Acetabular position b) Time required to determine optimal position	Post-acquisition test & transfer test	PT: In favour of terminal feedback (not significant)
					Group 3: Received terminal feedback after every trial	Visual-spatial ability a) Mental Rotations Test Part A	(10 min after the skill acquisition) Retention- & transfer test (6 weeks after the skill acquisition)	Retention test: PT: In favour of concurrent feedback (not significant)
O'Connor et al. [74]	RCT (3 arms)/ USA	*N* = 9 medical students (1st and 2nd year)	Unclear experience	Laparoscopic knot-tying and suturing (simulation)	Group 1: Received no feedback during the 4 weeks	Measurement of performance: a) Time	Measurement points during all practice sessions	Post-acquisition-test: PT: In favour of concurrent feedback (not significant)
					Group 2: Received KR at the end of each practice session	b) Instrument path length c) Smoothness of instruments		
					Group 3: Received KR and KP during and at the end of each practice session	d) Examination of each knot f) Error scale		

Table 2 Characteristics of included studies *(Continued)*

	Walsh et al. [75]	RCT/ Canada	*N* = 30 medical students (1st and 2nd year)	Novice learners	Colonoscopy (simulation)	Group 1: Received concurrent feedback (KP) Group 2: Received terminal feedback (KR)	Performance measures: a) Execution time b) 5-item Checklist (endoscopic performance) c) GRS	Pre-test Post-acquisition test (immediately after the practice) 2nd retention test (1 week after the intervention) Transfer test (1 week after the intervention)	Post-acquisition-test: PT: In favour of concurrent feedback (not significant) MD: In favour of concurrent feedback (not significant) Retention test: PT: In favour of concurrent feedback (not significant) MD: In favour of concurrent feedback (not significant) Transfer test: PT: In favour of terminal feedback (significant) MD: In favour of terminal feedback (significant)

ATLS Advanced Trauma Life Support, *GRS* Global Rating Scale, *KP* Knowledge of performance, *KR* Knowledge of results, *MD* Movement duration, *MI* Mental imagery, *mMIQ* modified Mental Imagery Questionnaire, *MP* Mental practice, *PSRS* Procedure Specific Rating Scale, *PT* Performance tests, *VH* Vaginal hysterectomy

Findings

Whole practice - part practice (WP-PP)

After the search three studies were included for the comparison whole practice against part practice. The procedure that was trained was either an orthopaedic surgical skill [9, 62] or a carotid stenting procedure [63] (see Table 2 for details).

Performance tests WP-PP

Three studies [9, 62, 63] provided data for this outcome. All studies used procedure specific checklists to measure the effect of the intervention on orthopaedic surgical tasks [9, 62] or on a carotid stenting procedure [63]. The results of a post-acquisition test (with 50 participants) immediately after the intervention showed a moderate effect size of 0.43 SMD (95 % CI -0.43 to 1.29) in favour for whole practice (p: 0.33). However, heterogeneity was considerable for this analysis (I^2: 54 %) (Fig. 2). Only Brydges et al. [9] measured the procedure on a transfer test (a cadaver bone was used instead of an artificial bone). The results of their study were in favour for part practice (SMD: -0.44, 95 % CI -1.59 to 0.71, p: 0.46).

Movement duration WP-PP

Two studies [9, 63] measured the time needed to perform the procedure. Both studies measured this outcome with a post-acquisition test within 5 min after the intervention for learning the procedure ceased. In total 32 participants were included for the post-acquisition test. The pooled effect size was 0.03 SMD (95 % CI -0.67 to 0.72, p: 0.93). Heterogeneity measured with I^2 was low (0 %). One study [9] measured results on a transfer test. The effect size of the transfer test was in favour for part practice (SMD: 0.30, 95 % CI -0.84 to 1.44, p: 0.61).

Random practice - blocked practice (RP-BP)

Performance tests RP-BP

Brydges and colleagues [9] and Dubrowski et al. [62] used procedure specific checklists to measure skill performance of orthopaedic surgical procedures (i.e. bone-plating task). Both studies measured performance on a post-acquisition test within 5 min shortly after the practice session. For the post-acquisition test 31 participants were included. The effect size was moderate (SMD: 0.63) and in favour for random practice (95 % CI -0.10 to 1.36). However, the result was statistically not significant (p: 0.09). Heterogeneity between studies was low (I^2: 0 %). Brydges et al. also measured the procedure on a transfer test. The results of the transfer test were in favour for the blocked practice but were statistically not significant (SMD: -0.22, 95 % CI -1.36 to 0.92, p: 0.71). Because only Brydges et al. was included for this analysis, a pooling was not possible (Fig. 3).

Movement duration RP-BP

One study [9] evaluated the effectiveness of a random practice intervention against a blocked practice intervention on the outcome movement duration for an orthopaedic surgical procedure (bone-plating). Twelve participants were analysed for this outcome. Effect sizes were small and close to zero (SMD: -0.16, 95 % CI -1.29 to 0.98 for a post-acquisition test and SMD: -0.06, 95 % CI: -1.20 to 1.07 for a transfer test).

Mental practice (MP)

After the selection process eight studies were included for this comparison. Five studies compared mental practice against a standard educational intervention (e.g.

	Whole practice			Part practice				Std. Mean Difference
Study	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Post acquisition test								
Brydges 2007	14.13	1.96	6	14.13	1.52	6	29.9%	0.00 [-1.13, 1.13]
Dubrowski 2005	5.72	2.49	9	2.22	2.52	9	32.3%	1.33 [0.28, 2.38]
Willaert 2011	24	5.46	10	24	5.96	10	37.7%	0.00 [-0.88, 0.88]
Subtotal (95% CI)			25			25	100.0%	0.43 [-0.43, 1.29]
Heterogeneity: $Tau^2 = 0.31$; $Chi^2 = 4.32$, df = 2 (P = 0.12); $I^2 = 54\%$								
Test for overall effect: Z = 0.98 (P = 0.33)								
Transfer test								
Brydges 2007	12.03	4.36	6	13.77	2.84	6	100.0%	-0.44 [-1.59, 0.71]
Subtotal (95% CI)			6			6	100.0%	-0.44 [-1.59, 0.71]
Test for overall effect: Z = 0.74 (P = 0.46)								

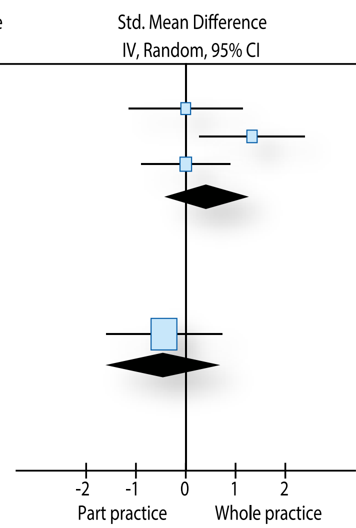

Fig. 2 Analysis performance tests whole practice - part practice. The forest plot relates to the outcome performance test. The outcome movement duration is not illustrated

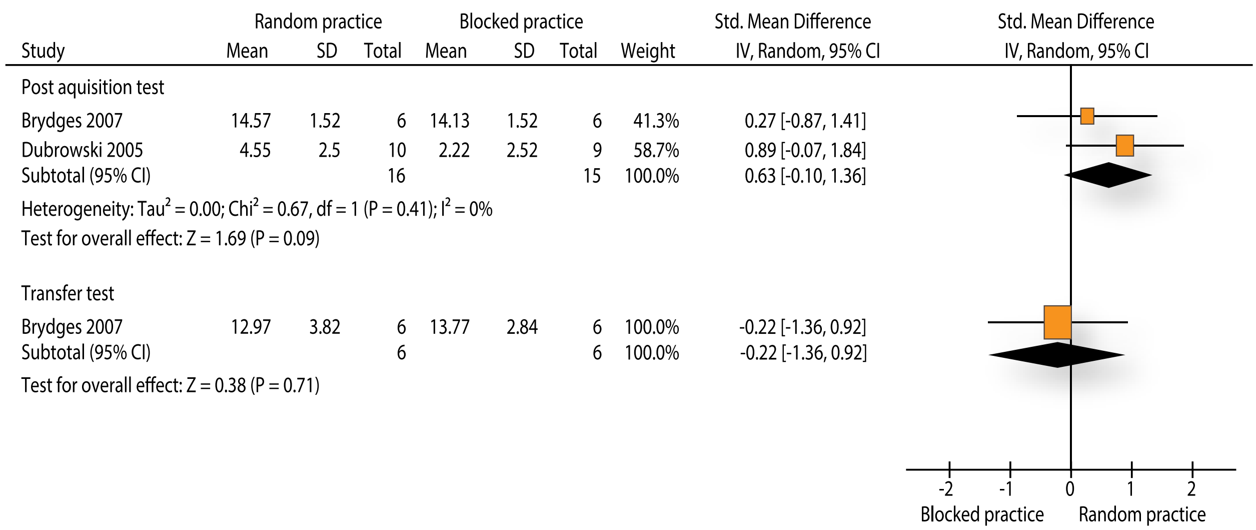

Fig. 3 Analysis performance tests random practice - blocked practice. The forest plot relates to the outcome performance test. The outcome movement duration is not illustrated

textbook readings) [65, 66, 68, 69, 71]. Two studies compared the effect of additional mental practice against no additional practice [64, 67]. One study [70] compared different quantities of mental practice and physical practice (see Table 2 for greater detail of interventions). All procedures with one exception were related to surgical education. The procedure outside the surgical domain was pelvic examination [69]. Two studies evaluated the influence of mental practice on basic surgical skills [70, 71]. Two studies trained laparoscopic procedures [64, 67]. Two studies evaluated the influence of mental practice in relation to surgical procedures in gynaecology [66, 68] and Bathalon and colleagues [65] were interested whether mental practice could have a beneficial influence on learning of a cricothyrotomy procedure.

Performance tests (MP)

Five studies [64, 66, 68, 70, 71] evaluated procedural skills with a performance test. In four studies the outcome measure was a global rating scale. Sanders et al. [71] used a combination of several specific rating scales. In total 241 participants were analysed. The pooled effect size was small to moderate (SMD: 0.43, 95 % CI 0.01 to 0.85) in favour of mental practice on a post-acquisition test. Furthermore, the result was statistically significant (p: 0.046). Heterogeneity was moderate (I^2: 59 %). Two of the above mentioned studies measured procedural performance also on a transfer test [70, 71]. Both studies provided data from 107 participants. The pooled estimate of the effect was small (SMD: 0.20, 95 % CI -0.56 to 0.97) and in favour for the mental practice group (Fig. 4). Furthermore, the effect was statistically not significant (p: 0.60) and heterogeneity was considerable (I^2: 74 %).

Movement duration (MP)

It was possible to include four studies for the outcome movement duration [65–68]. All measured the effect of mental practice on a post-acquisition test. The post-acquisition test was measured shortly or immediately after the intervention period. Only Bathalon and colleagues [65] scheduled their test two weeks after the intervention. In total 181 participants were analysed for this outcome. The pooled estimate was 0.00 SMD with a 95 % CI between -0.29 and 0.30. The result was statistically not significant (p: 0.98) and heterogeneity was low (I^2: 0 %).

Augmented feedback (AF)

Four studies compared different ways of giving feedback [72–75]. One study was based in a physiotherapeutic setting and evaluated whether learning of a joint mobilisation procedure benefitted more from terminal or a concurrent feedback. Gofton et al. [73] trained an orthopaedic surgical procedure with surgical residents and feedback was given as concurrent or terminal feedback. Walsh et al. [75] evaluated the learning of a colonoscopy procedure in medical students after receiving concurrent or terminal feedback. The study of O'Conor and colleagues [74] trained a laparoscopic procedure in medical students.

Performance tests (AF)

All four studies evaluated procedural skills. One study used a procedure specific checklist [75]. The remaining three studies measured this outcome with error scores. It was possible to compare three different endpoints. A first post-acquisition test shortly after the intervention (0-10 min after the last session) was measured by all

Study	Mental practice Mean	SD	Total	No mental practice Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Post acqusition test								
Arora 2011	27.5	4.23	9	19.5	4.23	9	6.0%	1.80 [0.66, 2.94]
Geoffrion 2012	4.4	5.8	23	2.4	4.8	25	15.4%	0.37 [-0.20, 0.94]
Komesu 2009	17.05	4.65	33	14.71	4.56	35	18.1%	0.50 [0.02, 0.99]
Sanders 2004	0.13	0.84	22	-0.17	0.9	22	14.7%	0.34 [-0.26, 0.93]
Sanders 2008	-0.05	0.86	31	0.04	1.06	32	17.8%	-0.09 [-0.59, 0.40]
Subtotal (95% CI)			118			123	100.0%	0.43 [0.01, 0.85]
Heterogeneity: $Tau^2 = 0.13$; $Chi^2 = 9.70$, df = 4 (P = 0.05); $I^2 = 59\%$								
Test for overall effect: Z = 1.99 (P = 0.046)								
Transfer test								
Sanders 2004	0.03	0.91	22	0.23	1.02	22	47.9%	-0.20 [-0.80, 0.39]
Sanders 2008	0.29	0.92	31	-0.26	0.96	32	52.1%	0.58 [0.07, 1.08]
Subtotal (95% CI)			53			54	100.0%	0.20 [-0.56, 0.97]
Heterogeneity: $Tau^2 = 0.23$; $Chi^2 = 3.86$, df = 1 (P = 0.05); $I^2 = 74\%$								
Test for overall effect: Z = 0.52 (P = 0.60)								

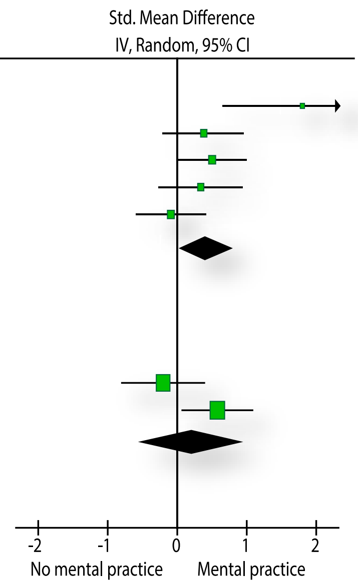

Fig. 4 Analysis performance tests mental practice. The forest plot relates to the outcome performance test. The outcome movement duration is not illustrated

four studies. In total 90 participants were included for this analysis. The pooled effect size for this analysis was 0.01 SMD (95 % CI: -0.46 - 0.33) and statistically not significant (p: 0.75). In addition three studies also measured a delayed retention test [72, 73, 75]. Results were homogenous (I^2: 0 %). The pooled estimate for this analysis was -0.35 SMD (95 % CI: -0.78 - 0.08) in favour for the concurrent feedback group and statistically not significant (p: 0.11). One study [75] with 30 participants measured procedural skills on a transfer test. They presented a large effect size in favour for the terminal feedback group (SMD: 0.94, 95 % CI 0.18 to 1.70) (Fig. 5).

Movement duration (AF)

Walsh et al. [75] presented data for this outcome. They evaluated three endpoints. An immediate post-acquisition test was in favour of the concurrent feedback group -0.48 SMD (95 % CI -1.21 to 0.25, p: 0.19). A delayed retention test (1 week after the intervention) was in favour for the concurrent feedback group as well (SMD: -0.20, 95 % CI -0.91 to 0.52, p: 0.59). Lastly, the results of a transfer test were clearly in favour for the terminal feedback group (SMD: 0.74, 95 % CI 0.00 to 1.48, p: 0.047).

Risk of bias assessment

All 15 included studies were evaluated on their risk of bias (Fig. 6). All studies had a high risk of bias because they didn't blind leaners and educators. Therefore, a performance bias must be assumed in all studies. All studies reported that they randomly generated groups but the method of the random sequence generation was often poorly reported. Furthermore, only four studies [66, 68, 70, 73] were judged with a low risk on allocation concealment. Therefore, a selection bias might have occurred in the majority of studies. A detection bias might have occurred in three studies [62, 67, 74] they were appraised as having an unclear risk of bias with regard to the blinding of outcome assessors. Five studies [64, 69–72] did not measure the outcome movement duration. Therefore, the corresponding items were not evaluated.

Discussion

Summary of main results

This review set out to explore the question, if teaching of procedural skills based on motor learning principles is effective for skill acquisition and skill retention in physiotherapy and medical education? Four different motor learning principles were evaluated. We could include 15 studies in this systematic review. The majority of studies investigated use of mental practice ($n = 8$). Only two studies compared random practice against blocked practice, three studies evaluated part practice against whole practice and four studies investigated augmented feedback.

The comparison whole practice versus part practice showed no statistically significant results. Despite being not significant, performance tests indicated that results of a post-acquisition test were in favour for whole practice, therefore possibly indicating that WP improves immediate performance of skill after a period of training. For longer term outcome, performance seemed to be more effective on a transfer test when a part practice regime was followed. Effect sizes were small to moderate

Study	Concurrent Feedback Mean	SD	Total	Terminal feedback Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Post aquisition test								
Chang 2007	0.46	0.52	12	0.34	0.34	12	26.7%	0.26 [-0.54, 1.07]
Gofton 2007	0.69	2.98	15	0.18	2.91	15	33.6%	0.17 [-0.55, 0.89]
O'Connor 2008	1.96	1.25	3	2.64	0.84	3	6.2%	-0.51 [-2.19, 1.16]
Walsh 2009	-19.88	3.4	15	-18.99	3.52	15	33.5%	-0.25 [-0.97, 0.47]
Subtotal (95% CI)			45			45	100.0%	0.01 [-0.40, 0.43]
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 1.44$, df = 3 (P = 0.70); $I^2 = 0\%$								
Test for overall effect: Z = 0.06 (P = 0.96)								
Retention test								
Chang 2007	0.46	0.38	12	0.54	0.38	12	29.0%	-0.20 [-1.01, 0.60]
Gofton 2007	0.23	2.91	15	2.14	3.83	15	35.0%	-0.55 [-1.28, 0.18]
Walsh 2009	-20.32	2.63	15	-19.51	3.06	15	36.1%	-0.28 [-1.00, 0.44]
Subtotal (95% CI)			42			42	100.0%	-0.35 [-0.78, 0.08]
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.45$, df = 2 (P = 0.80); $I^2 = 0\%$								
Test for overall effect: Z = 1.59 (P = 0.11)								
Transfer test								
Walsh 2009	-15.06	2.94	15	-17.93	2.98	15	100.0%	0.94 [0.18, 1.70]
Subtotal (95% CI)			15			15	100.0%	0.94 [0.18, 1.70]
Test for overall effect: Z = 2.43 (P = 0.01)								

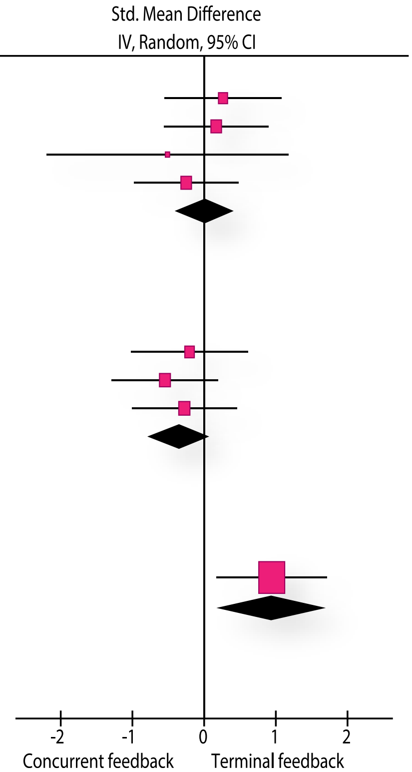

Fig. 5 Analysis performance tests terminal feedback - concurrent feedback. The forest plot relates to the outcome performance test. The outcome movement duration is not illustrated

on the transfer test. Only one study [9] used a transfer test to evaluate the effectiveness of the intervention on a similar procedure. Three studies and therefore considerably more participants were available for the post-acquisition test. However, post-acquisition tests provide only limited evidence of learning and the observed changes may be related to transient changes in performance and it is difficult to estimate the amount of learning that has occurred with these tests. Little educational diversity was present with regard to the length of the time interval between the intervention and the administration of the post-acquisition test (i.e. measured immediately or 5 min after the intervention). In contrast educational diversity was present with regard to the participant's level of experience. Experience ranged between novices [62] and some experience in a related procedure [63]. This is of particular importance because part practice might be helpful for novice learners [76]. According to motor learning theory a part practice approach might be applicable for skill learning due to a reduced intrinsic load of the task for the learner. Especially novice learners might benefit from a load reducing approach, which increases the resources available for the learning process itself [76]. In contrast learners with a higher skill level are assumed to benefit less from a part practice schedule [77].

The evaluation of random practice against blocked practice did not show a statistically significant result. Random practice appeared more beneficial for immediate performance after a period of training, however this improvement did not persist on a transfer test. This effect in the opposite direction of the expected direction might be explained by the complexity of the procedures. Effects of random versus blocked practice are a relatively robust phenomenon in simple tasks [78]. However, evidence is less clear with regard to complex tasks [78]. Both included studies trained procedures that can be classified as complex, which may have caused the unexpected result. However, task complexity differed between the test conditions. An artificial bone was used during the acquisition phase and for the post-acquisition tests. Brydges et al. [9] reported that the complexity of the task was moderate with regard to the skill level of the participants. Random practice might have positively influenced immediate performance because task complexity for the learners was only moderate and learners might have benefitted from deeper and more elaborative memory processes (i.e. a more intense motor planning) caused by random practice. During the transfer test a cadaver bone was used and complexity was significantly increased for the participants. The higher task complexity of the transfer test compared to the complexity

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias): Movement duration	Blinding of outcome assessment (detection bias): Procedure performance	Incomplete outcome data (attrition bias): Movement duration	Incomplete outcome data (attrition bias): Procedure performance	Selective reporting (reporting bias)
Arora 2011	+	?	−		+		+	+
Bathalon 2005	?	?	−	+	+	+	+	+
Brydges 2007	?	?	−	+	+	+	+	+
Chang 2007	?	?	−		+		+	+
Dubrowski 2005	?	?	−	?	?	+	+	+
Geoffrion 2012	+	+	−	+	+	−	−	+
Gofton 2007	+	+	−	+	+	+	+	+
Jungmann 2011	?	?	−	?	?	+	+	+
Komesu 2009	+	+	−	+	+	+	+	+
O'Connor 2008	?	?	−	?	?	+	+	+
Rakestraw 1983	?	?	−		+		+	−
Sanders 2004	+	+	−		+		+	+
Sanders 2008	?	?	−		+		+	+
Walsh 2009	?	?	−	+	+	+	+	+
Willaert 2011	+	?	−	+	+	+	+	+

Fig. 6 Risk of bias evaluation

of the acquisition phase might have prevented the participants to fully benefit from random practice. A similar finding of a reversed effect of random versus blocked practice on transfer tests was reported by Albaret and Thon [79] when they considerably increased the complexity of practiced tasks. With regard to educational diversity both studies were relatively homogenous. This included the use of similar measurement scales and procedures.

The use of mental practice resulted in significant increases of performance on a post-aquisition test. A transfer test was in favour for mental practice but did not reach the level of significance. No statistically significant results were found for the outcome movement duration. The effectiveness of mental practice on performance tests included five randomised controlled trials. Educational and methodological heterogeneity was considerable for this comparison. Most importantly in two studies [64, 67] there was no active comparator. This might have introduced a bias in favour of mental practice. This is especially true for the study of Arora and colleagues [64]. There was diversity in relation to the included participants. The spectrum ranged from undergraduate medical students to surgical and gynaecology residents. Furthermore, the participants experience varied between no prior experience to some experience with the procedure. Little heterogeneity was present for the measurement and all studies measured the post-acquisition test immediately after the training period.

Performance was statistically significant better when the feedback was given as terminal feedback on a transfer test. Concurrent feedback seemed to be superior on a delayed retention test with regard to the outcome performance tests. However, the finding did not reach the level of statistical significance. The superiority of the terminal feedback on the transfer test might be explained by the guidance hypothesis [80], which states that initial performance can benefit from frequent feedback but in later stages learners might develop a dependency on feedback and therefore performance on a transfer test without feedback might be reduced. However, the guidance hypothesis cannot explain the findings of the delayed retention test. Performance of procedures was measured differently compared with the other three comparisons. Three studies used participant's errors [72–74]. Only one study [75] used a procedure specific checklist. The procedure that was trained differed because one study [72] was based in physiotherapy and the remaining three procedures were surgical procedures. The participants were either students or surgical residents. Their experience level ranged between novice learners to some prior experience. Furthermore, there was considerable diversity with regard to the length of the retention interval of the delayed retention test. The time point of measurement ranged between five days [72] and 6 weeks [73].

Quality of the evidence

The risk of bias of included studies was universally high. This was inevitable because a blinding of learners and educators was difficult or nearly impossible achieve for these interventions. Furthermore, all included studies claimed to be randomised controlled studies. But only four studies [66, 68, 70, 73] sufficiently described the process of randomisation. The chance of selection bias is significantly reduced with a randomised controlled trial design. But when the selection procedure is not described in detail it is unclear whether this important threat to internal validity is avoided. It was not possible to exclude a detection bias in this review, because blinding of outcome assessors wasn't explicitly reported by all studies. As blinding of outcome assessors is especially important for subjective outcome measures the outcome procedure performance is probably at higher risk to systematic measurement error than the outcome movement duration.

Potential biases in the review process

The strength of this review was the systematic procedure. Studies were selected with clearly defined inclusion and exclusion criteria. Risk of bias of all studies was assessed using the Cochrane's risk of bias tool [25] and it was possible to perform a meta-analysis for all comparisons and for all outcome measures. One weakness of this review was that it was necessary to extract data from several studies from graphical representations as numerical data were not available [9, 72, 73, 75]. It is not possible to exclude any imprecision from this process. However, arguably any imprecision might have occurred in both directions.

A further limitation of this review was that only few studies and participants could be included in the analysis. Especially, the comparisons WP - PP (three studies) and RP - BP (two studies) might suffer from a small study bias [81]. Furthermore, the following features might have influenced the findings.

The majority of studies used a simulated environment and only MP was also applied in real world practice [66, 68]. Educational dimensions may differ between simulation and practice. Application of the procedures in real practice may also involve other dimensions than solely procedural skills (e.g. dimensions such as communication and decision-making). Therefore, learners and educators might vary their strategies to train a procedural skill depending on whether other dimensions were also included in the training. Furthermore, assessment methods varied between simulation based training (e.g. computed based metrics [67]) and practice based training (e.g. attending surgeons evaluation [66]). This might have introduced a bias in the MP findings. A limitation of the other three comparisons is that the transfer of the evidence into practice needs to be further evaluated.

A further limitation of this review is that the spectrum, of included learners ranged between undergraduates (novices) and postgraduates (experts). All studies aimed to train a novel procedure. However, learning might be different in novices and experts. Latter might benefit from transfer of learning from previous learned similar procedures. This limitation might especially concern the findings of the WP-PP analysis.

Lastly, task complexity varied between procedures. All of the procedures can be classified as reasonable complex procedures because they fulfil at least two features of complex procedures when the framework of Wulf and Shea [78] is used. Firstly, it is not likely to learn them in a single session. Secondly, all procedures involve movements of more than one degree of freedom. But the last feature of complex procedures (i.e. ecological validity) was not completely fulfilled by the simulation studies, because they are trained in an artificial environment. This may affect the analysis of MP, because highly complex real world procedures were analysed together with complex simulation procedures.

Agreements with other studies

The finding from this review, that part practice was not superior to whole practice on a retention test is also supported by a meta-analysis of Wickens et al. [77]. Their review was related to the field of military procedures and therefore findings are only partial comparable to this review. The authors reported that part practice had limitations in some of their included studies. Especially, when parts of a procedure were created by fractionation they observed a failure of part practice. This might have lead to a separation of time dependent parts and learners possibly did not develop relevant time-sequencing skills [77].

The finding of this review that mental practice is effective is supported by studies in related fields. Already in 1988 Feltz and Landers showed that motor imagery has a positive effect on skill learning [82]. More recently Braun et al. [83] showed that mental practice also had some beneficial influence on skill learning in a population with stroke survivors. A concept why mental practice may be effective for the learning of procedures was introduced by Jeannerod [84] with the functional equivalence hypothesis. This theory is build upon the assumption that when a movement is imagined, the brain activity is similar to the brain activity of a physical execution of this movement. Hétu et al. [85] supported the theory in a meta-analysis by identifying a large neural network in motor related regions that is activated by mental practice. However, the primary motor cortex, which is normally active during physical practice, was not consistently activated during mental practice. This indicates that mental practice can be seen as a support of physical practice and not a replacement.

A recent systematic review [29] evaluated the role of augmented feedback for procedural learning in medical education. Their findings were similar to this review. However, they didn't analyse a transfer test, which was in favour of terminal feedback.

Finally, while all the studies included in this review related to the teaching and acquisition of complex motor skills, only one of the 15 studies specifically referred to physiotherapeutic procedures. Therefore, any inferences in relation to structuring of teaching and practice of complex therapeutic motor skills should be made with extreme caution.

Conclusions

There is some evidence to recommend the use of mental practice for procedural learning in medical education. Especially, surgical skills benefitted from mental practice. In order to improve learning of procedures this motor learning principle should be considered for implementation. There is limited evidence to conclude that terminal feedback is more effective than concurrent feedback on a transfer test. However, only one study showed this effect and future studies need to support this finding. Therefore, it may be justified to cautiously use this kind of feedback. There were indications that whole training has some advantages over part training on immediate post-acquisition tests. However, evidence was not strong enough to justify the integration of this principle in curricula. The same relates to the use of random practice. The limited evidence of improved performance on post-acquisition tests might support the use of this principle in some circumstances. In addition, educators should be aware that it is not safe to make inferences about learning with post-acquisition tests. This should encourage faculty to implement delayed retention and transfer tests to assess the learning of procedures.

The evidence available for the reviewed motor learning principles is not strong enough to draw strong conclusions about effectiveness, therefore there is a need for more studies with adequate design (i.e. randomised controlled trials) and sufficient sample size. With the exception of the principle mental practice, less than five randomised controlled studies were available for analysis for each of the selected motor learning principles. Furthermore, sample sizes of the studies were small and only two studies (both for the principle mental practice) had sample sizes over 30 participants per trial arm. Most studies evaluated the application of motor learning principles in surgical education. Therefore, there is a demand for research in other HPE settings where complex procedural skills are taught.

Additional file

Additional file 1: Practical application of the motor learning principles. (DOCX 110 kb)

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

MS conceived the study, participated in its design, was involved in the selection process, extracted data, evaluated the risk of bias and performed the statistical analysis. SE was involved in the selection process, extracted data and evaluated the risk of bias. RH performed the statistical analysis. GB conceived the study and participated in its design and interpretation. All authors have been involved in drafting or critically revising the manuscript for important intellectual content. All authors read and approved the final manuscript.

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A systematic review of assessments for procedural skills in physiotherapy education

Assessment von prozeduralen Fähigkeiten in der physiotherapeutischen Ausbildung: Ein systematischer Review

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Abstract

Introduction: Learning of procedural skills is important in the education of physiotherapists. It is the aim of physiotherapy degree programmes that graduates are able to practice selected procedures safely and efficiently. Procedural competency is threatened by an increasing and diverse amount of procedures that are incorporated in university curricula. As a consequence, less time is available for the learning of each specific procedure. Incorrectly performed procedures in physiotherapy might be ineffective and may result in injuries to patients and physiotherapists. The aim of this review was to synthesise relevant literature systematically to appraise current knowledge relating to assessments for procedural skills in physiotherapy education.
Method: A systematic search strategy was developed to screen five relevant databases (CINAHL, Cochrane Central, SportDISCUS, ERIC and MEDLINE) for eligible studies. The included assessments were evaluated for evidence of their reliability and validity.
Results: The search of electronic databases identified 560 potential records. Seven studies were included into this systematic review. The studies reported eight assessments of procedural skills. Six of the assessments were designed for a specific procedure and two assessments were considered for the evaluation of more than one procedure. Evidence to support the measurement properties of the assessment was not available for all categories.
Discussion: It was not possible to recommend a single assessment of procedural skills in physiotherapy education following this systematic review. There is a need for further development of new assessments to allow valid and reliable assessments of the broad spectrum of physiotherapeutic practice

Abstract

Einleitung: Das Erlernen von prozeduralen Fähigkeiten ist ein wichtiges Element in der Ausbildung von Physiotherapeuten/-innen. Es ist das Ziel von physiotherapeutischen Studiengängen, Graduierte zu befähigen, ausgewählte Prozeduren sicher und effektiv auszuführen. Die prozedurale Kompetenz ist bedroht von wechselnden und einer stetig anwachsenden Anzahl von Prozeduren, die in die Curricula der Studiengänge eingebaut werden. Als Konsequenz ist weniger Zeit vorhanden, um die einzelnen Prozeduren zu erlernen. Falsch durchgeführte Prozeduren können zu Verletzungen von Patienten/-innen und Physiotherapeuten/-innen führen. Zielsetzung dieser Arbeit war es, relevante Literatur systematisch zu erfassen, um eine Übersicht von Assessments von prozeduralen Fähigkeiten in der physiotherapeutischen Ausbildung zu erstellen.
Methode: Eine systematische Suchstrategie wurde entwickelt, um fünf Datenbanken (CINAHL, Cochrane Central, SportDISCUS, ERIC und MEDLINE) nach relevanten Studien zu durchsuchen. Die eingeschlossenen Assessments wurden bezüglich Reliabilität und Validität bewertet.
Ergebnisse: Die Suche in den elektronischen Datenbanken ergab 560 Treffer. Sieben Studien wurden in diese systematische Übersichtsarbeit eingeschlossen. Die Studien berichteten über acht Assessments für prozedurale Fähigkeiten. Sechs Assessments sind für eine spezifische Prozedur entwickelt worden und zwei Assessments können für unterschiedliche Prozeduren benutzt werden. Evidenz für die Messeigenschaften der eingeschlossenen Messinstrumente war nicht für alle Kategorien verfügbar.
Diskussion: Es ist nicht möglich, ein bestimmtes Messinstrument zur Bewertung von prozeduralen Fähigkeiten zu empfehlen. Es gibt einen Bedarf an Messinstrumenten, die reliabel und valide sind, um das breite Spektrum von prozeduralen Fähigkeiten zu bewerten.

Keywords
Procedural skills – practical skills – systematic review – clinical assessment

Keywords
Prozedurale Fähigkeiten – praktische Fähigkeiten – systematischer Review – klinisches Assessment

INTRODUCTION

It is the aim of physiotherapy degree programmes that graduates are able to execute selected procedures safely and efficiently. Considerable resources are allocated to enable graduates to achieve a high level of procedural competency. Within this review, procedural skills were classified after Kent's definition as: 'a skill involving a series of discrete responses each of which must be performed at the appropriate time in the appropriate sequence' (Kent, 2007, p. 437).

Recent literature highlights that there is no consensus with regard to definitions and classifications of procedural skills. Michels, Evans, and Blok (2012) identified that procedural skills are not exactly defined in the field of health professions education. Frequently, they are categorised under the umbrella term 'clinical skills'. However, there is a lack of standardisation. Simpson et al. (2002) separated the practical procedures from communication skills, clinical skills, and other skills in the Scottish doctor learning outcomes. In contrast, the General Medical Council in the UK does not separate between procedural skills and clinical skills (2004), for example, safety measures are categorised as essential procedural skills in their classification. Lastly, the Royal Australian College of General Practitioners (2011) defined procedural skills as: 'A procedure is a manual intervention that aims to produce a specific outcome during the course of patient care' (The Royal Australian College of General Practitioners, 2011, p . 515).

To avoid ambiguity in this review, procedural skills were characterised with the following features: a) they involve the execution of a procedural task (e.g., a manual or a practical task), b) involvement of technical equipment may be possible but this is not a prerequisite of procedural skills, c) the character of a procedure can be diagnostic, evaluative or interventional and d) procedures can range from simple tasks with few parts to complex sequences involving multiple activities.

As procedures in physiotherapy are highly interactive between patients and therapists, more information than the execution of procedures may be needed to evaluate the procedural skills. For example, communication providing basic information about the procedures between physiotherapist and patient is frequently necessary. Consequently, therapists should be educated to allow them to adapt procedures to a variety of circumstances such as environmental requirements or individual patient needs.

Physiotherapy is a dynamic profession with evolution of new physiotherapeutic roles and skills in many health systems (Higgs, Hunt, Higgs, & Neubauer, 1999), thus requiring the incorporation of new tasks and skills into physiotherapy degree curricula. However, this may result in an increased amount of procedures that are incorporated in university curricula. As a consequence, less time is available for the learning of specific procedures.

Incorrectly performed procedures in physiotherapy might be ineffective and may result in injuries to physiotherapists or to patients. For example, Nyland and Grimmer (2003) reported that low back pain is frequently experienced by undergraduate physiotherapy students and, Glista and co-workers (2014) reported that the students' posture deteriorated during the course of education. In some situations, physiotherapists are required to perform professional procedures in difficult environments with poor working postures which are potentially harmful for the musculoskeletal system (Jackson & Liles, 1994). Therefore, training of procedures should be designed to enable learners to perform procedures without endangering their own personal safety and to understand how to adapt procedures appropriately.

Procedures performed by physiotherapist can also be associated with adverse events for patients. For example, Gorrell, Engel, Brown, and Lystad (2016) reported that mild adverse events occurred in 61 RCTs and major adverse events were seen in 2 RCTs evaluating the spinal manipulative therapy. Therefore, following the initial teaching of procedural skills, physiotherapy educators need valid and reliable assessment tools to evaluate whether procedural competency of students is sufficient for practice.

Assessment of procedural skills has been extensively researched in surgical education (Jelovsek, Kow, & Diwadkar, 2013). Some assessments exist, which can be used for procedures in nursing education (Morris, Gallagher, & Ridgway, 2012). While teaching of procedural skills is a core part of undergraduate physiotherapy education, no review could be identified of assessment tools for procedural skills in physiotherapy education.

One important consideration in the evaluation of procedural skills in physiotherapy is whether an assessment framework exists. Miller (1990) argued that no single assessment would be sufficient to allow the judgement of such complex skills. He presented a four-level framework for assessments in health professions education. The base of this framework is knowledge (the student 'knows'), which can be tested with standardised objective test methods (e.g., multiple choice tests). The second level (competence) provides evidence that students know how to use their knowledge (e.g., vignette assessments). The third level evaluates the performance of students (e.g., students have to show how they perform a specific procedure). Lastly, the question remains whether the learned skills are independently selected and used appropriately in clinical practice. Examples to evaluate the 'action level' are work place based assessments or portfolios (Chandratilake, Davis, & Ponnamperuma, 2010).

The aim of this review was to identify, examine and synthesise relevant literature to produce a systematic review of assessments for procedural skills in physiotherapy education. Specifically, the objective of this review was to identify existing assessments of procedural skills in physiotherapy education and to evaluate them with regard to their measurement properties.

METHODS

A systematic review was undertaken to address the identified objectives. To increase clarity of reporting, the PRISMA guideline was followed (Liberati et al., 2009).

Criteria for inclusion and exclusion

Inclusion and exclusion criteria are presented in Table 1.

Search methods

Five electronic databases were systematically searched for potential eligible studies. These databases were: Cumulative Index to Nursing and Allied Health Literature (CINAHL), Cochrane Central Register of Controlled Trials (CENTRAL), SPORTDiscus, Educational Resource Information Center (ERIC) and Medline via Pubmed. In addition, the references of all included full text articles were checked for relevant studies. The search string is presented in Table 2. Findings of the three categories Population, Assessment and Outcome were combined with the Boolean operator AND.

All retrieved records were imported into an electronic database and duplicates were removed. In the next step, titles and abstracts of the records were screened with regard to the pre-specified inclusion and exclusion criteria. Lastly, the full texts of the remaining studies were read and studies were included in the systematic review if they met all criteria.

Table 1: In-and exclusion criteria

Category	Criteria
Population	**Studies with physiotherapists or physiotherapy students were included.**
	Studies with health professionals or health professions students were included when they practiced procedures that can be used in physiotherapy (i.e., when medical students were evaluated on their ability to perform a musculoskeletal examination)
	Studies with health professionals or health professions students were excluded when they practiced procedures that cannot be practiced by physiotherapists (such as surgery)
Educational assessments	**The assessment could be either a procedure specific measurement instrument (i.e., the assessment is designed exclusively for one procedure) or a procedure unspecific measurement (i.e., the assessment is designed to measure procedures in physiotherapy education but can be used for more than one procedure)**
	The assessment should measure procedures in reality. Assessments based on virtual reality were excluded.
	The assessment should be feasible in various settings. Therefore, assessments that require expensive equipment were excluded.
	Data must be available for a specific assessment. Studies with summary data of several assessments were excluded (e.g., summary scores of a complete OSCE).
Outcome	**The aim of assessment should be to measure procedural skills. Assessments of similar constructs such as clinical skills or psychomotor skills [defined as '… motor skill, some manipulation of material, or some act which requires a neuromuscular action' Simpson (1966, p. 17)] were included.**
	Assessments that aimed to exclusively evaluate other outcomes such as communication skills or professionalism were excluded.
	When assessments were designed to measure multiple outcomes, it was evaluated whether the focus was based on procedural skills (e.g., more than 50% of the items concentrate on procedural skills). The assessments with focus on procedural skills were included.
Measurement properties	**Studies had to report the measurement properties of an educational assessment (e.g., reliability or validity)**

Table 2: Search strategy

Population	Assessment	Outcome
medical education OR education, medical[Mesh] OR physiotherapy education OR physical therapy education OR health professions education OR healthcare education OR allied health care education	scale OR global rating scale OR GRS OR checklist	practical skill* OR psychomotor skill* OR procedural skill* OR clinical skill*

Data collection and management

Data were extracted in relation to the following information:

- Study details (country, setting and sample)
- Assessment characteristics (name of the assessment, assessment items, assessment aim, assessment duration, assessment criteria, assessors, patients and target procedure)
- Measurement properties (internal consistency, reliability, measurement error, content validity and construct validity)
- Methodological quality of assessments (the Standards for Evaluating the Quality of Assessment Methods in Medical Education (Swing, Clyman, Holmboe, & Williams, 2009)

Analysis

Evidence of reliability and validity of the included assessments was evaluated. Within reliability the internal consistency, the inter- and intra-rater reliability and the measurement error were appraised. Validity was appraised with regard to content validity, criterion validity and construct validity. Despite some discussion about agreed definitions regarding measurement properties, the consensus definitions proposed by Mokkink et al. (2010) were used to ensure consistency in how findings were interpreted.

Assessment of methodological quality of assessments

All included assessments were evaluated with the Standards for Evaluating the Quality of Assessment Methods (SEQAM) (Swing et al., 2009). The SEQAM is an assessment tool for educational assessments specifically designed for health professions education. The SEQAM critically evaluates 6 dimensions: reliability (e.g., reliability indicators are available for all used scores), validity (e.g., selection of content is justified), ease of use (e.g., the tool is easily carried out in daily practice), resources required (e.g., training requirements for assessors do not exceed one hour), ease of interpretation (e.g., individual scores are interpretable) and educational impact (e.g., provides useful results). For each dimension, the studies could be rated as evidence level A, B, C or not rated. For an evidence level of A, all standards of one dimension had to be met. Studies were rated as evidence level B when one standard was not met. When two standards in one dimension were not met, an evidence level of C was specified. Lastly, when three or more standards were not met, an evidence level of not rated (NR) was given. The scoring rules of the SEQAM were adapted from Swing et al. (2009).

RESULTS

The results of this review are presented in three sections. First the results of the search are presented, then the findings of measurement properties of the included assessments are provided. Finally, the methodological quality of the included assessments is considered.

Results of the search

The search of electronic databases identified 560 potential records. Additionally, 10 articles were identified by reference checking. It was possible to delete 6 duplicates. Therefore, titles and abstracts of 564 records were screened. The majority of 454 records were excluded because they did not report an appropriate assessment (n= 387). Fifty records did not report an appropriate outcome and 17 records did not meet the inclusion criteria with regard to the population.

110 full-text articles were then read. It was possible to exclude 103 full-text articles. Most studies (n = 93) were excluded because they were related to a different discipline in medicine (e.g., surgery). Two studies had insufficient data to include them into the systematic review. They evaluated multiple different patient encounters, and therefore, it was not possible to extract data for a single assessment method. Eight studies were not included because they were reviews of primary studies. Finally, seven studies were included into this systematic review. The studies reported six procedure specific measurement instruments (PSMI) and two procedure unspecific measurement instruments (PUMI) (Figure 1).

Included assessments

The included assessments were classified as either procedure specific measurement instruments (i.e., assessments designed for one specific procedure) or procedure unspecific measurement instruments (i.e., generic assessments, which can be used for more than one specific procedure).

Procedure specific measurement instruments

The six PSMIs included in this review are briefly presented below. A detailed critical overview is presented in Table 3. The Assessment of Musculoskeletal Physical Examination Skills Checklist (AMPE) was published by Beran et al. (2012). The AMPE is a 12-15 item checklist and evaluates the ability of health professionals to perform a physical examination of four different clinical scenarios. The scenarios involve an upper extremity, a trauma, a spine and a lower extremity case. The AMPE requires, in addition to an assessor, a trained standardised patient for each of the four scenarios. The authors designed checklists of important procedures, which the students

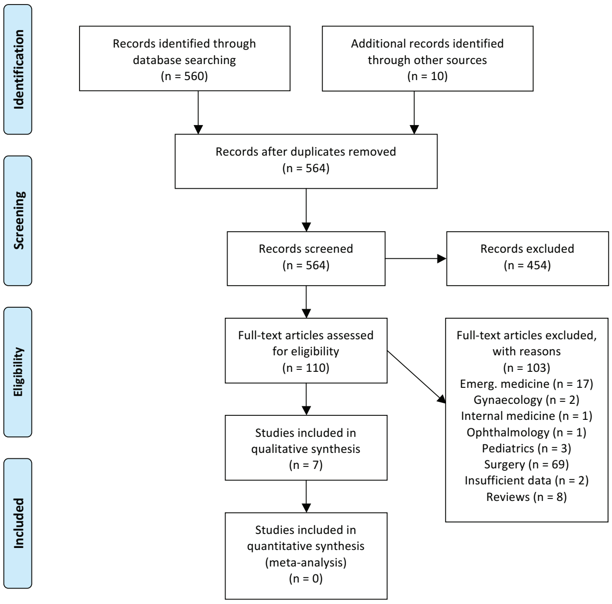

Figure 1: Study flow.

should perform when they encounter a specific simulated patient, such as joint palpation or strength testing.

Herbers, Wessel, El-Bayoumi, Hassan, and St Onge (2003) created the 29-item Pelvic Examination Skills Checklist (PES-C) and the 5-point Pelvic Examination Skill Rating Scale (PES-R). Most of the 29 items on the PES-C are related to the physical performance of a pelvic examination, although some of the items relate to communication skills (e.g., item 21: Tells patient to state if pain too great). The PES-R is a five-point global rating scale that enables the evaluator to rate the overall performance of the pelvic examination. Both assessments were validated with gynaecologic teaching associates who fulfilled a dual role as subjects for the pelvic examination and evaluators of the learner's performance within the study of Herbers and colleagues.

The Physical Examination Skills Checklist (PhyES) was published by Ladyshewsky, Baker, Jones, and Nelson (2000) and aims to evaluate a musculoskeletal physical examination of a patient with a rotator cuff problem. The PhyES is scored on a three-point system and uses carefully coached persons to portray specific patients. Performance was scored using a checklist which included important features of the physical examination (e.g., evaluation of shoulder girdle stability).

Swift and colleagues (2013) designed the mOSCE-Station 3 checklist (mO-S3). The mO-S3 evaluates the ability of physiotherapy students to perform two specific shoulder assessment tests. Learners have to choose two tests to confirm their hypothesis with regard to a scenario with a patient suffering from shoulder pain. The mO-S3 consists of five dichotomous items and one ordinal item. In order to administer the mO-S3, standardised patients and specialised clinical instructors are necessary. The following tasks were evaluated in the OSCE: i) think station, ii) explanation of the primary hypothesis to a patient, iii) performing two specific tests to confirm the hypothesis, iv) performing the best day 1 hands-on intervention, v) reassessment, vi) performing the best day 1 exercise intervention and vii) performing a specific technique and explanation of the selected technique.

The 138 item checklist head- to-toe physical examination checklist (HTTPE) (Yudkowsky et al., 2004) evaluates the ability of an 'assessor' to perform a complete physical screening examination of the whole body and all 138 items are scored on a trichotomous scoring system. To administer the HTTPE, trained standardised patient instructors are required. The patient instructors serve as patients and mark the 'assessors' performance.

Procedure unspecific measurement instruments

The Osteopathic Manipulative Treatment assessment tool (OMT) (Boulet, Gimpel, Dowling, & Finley, 2004) aims to measure the ability to perform a manipulative treatment and consists of 15 items scored on a trichotomous scale. It can be used for different manipulative treatment techniques and for different body regions and therefore is procedure unspecific. For example, Boulet et al. (2004) used the OMT to evaluate various procedures related to the treatment of low back pain, frozen shoulder or asthma. Standardised patients are a prerequisite to use the OMT as an assessment tool.

The Global Procedural Skills Evaluation Form (GPSE) was originally presented in the field of family medicine (Nothnagle, Reis, Goldman, & Diemers, 2010). However, its generalised design as a rating scale for procedural skills affords its utility for the assessment of procedural skills in physiotherapy as well. The GPSE provides feedback based on direct observation of a procedure. The scoring system is based on a 4-point scale and quantifies the amount of guidance that was needed to perform a procedure. No standardised patients are required when the GPSE is applied. Furthermore, student's self-assessment is included in the GPSE score.

Findings

Within this section, the evidence of measurement properties of the included assessments are presented. The consensus definitions proposed by Mokkink et al. (2010) were used to appraise the measurement properties.

Reliability

Reliability of the assessments was appraised with regard to their internal consistency, inter-rater reliability, intra-rater reliability and measurement error.

Table 3: Characteristics of included studies and assessments.

Study	Country	Setting	Sample	Assessed procedure	Scale and items	Duration	Patients	Assessors	Purpose
Beran et al. (2012) AMPE	USA	Orthopaedic department	24 orthopaedic residents	PSMI: Musculoskeletal physical examination; Inspection, palpation, joint range of motion, strength testing and any special tests pertinent to the clinical scenario	Four 12-15 items checklists for clinical scenarios (upper extremity, lower extremity, trauma and spine) on dichotomous scales (yes or no).	10 Minutes	Standardised patients are required (120 minutes training)	Pool of experienced raters	High stakes purpose
Boulet et al. (2004) OMT	USA	Osteopathic college	121 osteopathic students (4th year)	PUMI: Osteopathic manipulative treatment of three clinical cases (low back pain, frozen shoulder and asthmatic with cough)	OMT (Osteopathic Manipulative Treatment) assessment tool with 15 items; Every item is scored on a 0 to 2 scale (0 = done incorrectly or not done, 1 = not performed optimally and 2 = done proficiently)	13 minutes	Standardised patients with 8 hours of formal training	16 osteopathic physicians (5 hours of formal training)	High stakes examination (OSCE)
Herbers et al. (2003) PES-C	USA	University Medical Centre	72 internal medicine residents	PSMI: Pelvic examination	29 item dichotomous checklist (yes = when the behaviour was observed; no = when the behaviour was not observed); Includes some items about communication skills	Not specified	Gynaecologic teaching trainer required; 1 trainer was being examined and the second trainer rated the student's skills.	Gynaecologic teaching trainer required	Not specified
Herbers et al. (2003) PES-R	USA	University Medical Centre	72 internal medicine residents	PUMI: Pelvic examination	Global rating scale evaluating the overall performance of the pelvic examination (five-point ordinal scale between 1 = inadequate and 5 = excellent)	Not specified	Gynaecologic teaching trainer required; 1 trainer was being examined and the second trainer rated the student's skills	Gynaecologic teaching trainer required	Not specified
Ladyshewsky et al. (2000) PhyES	Australia	Physiotherapy department	12 under-graduate physiotherapy students 4 physio-therapists (at least 2 years of experience)	PSMI: Musculoskeletal physical examination of a patient with a rotator cuff problem	Physical examination checklist (3-point scale: 0 = not done, 1 = done poorly or incompletely and 2 = done well), number of items not available	Mean 30 minutes (range: 20 - 46 minutes)	Standardised patients are required	Assessors with 30 hours of training	High stakes examination (OSCE)

Continued Table 3: Characteristics of included studies and assessments.

Study	Country	Setting	Sample	Assessed procedure	Scale and items	Duration	Patients	Assessors	Purpose
Nothnagle et al. (2010) GPSE	USA	Family medicine department	5 faculty members and 5 students (semi structured interviews); Focus groups: 7 experienced family medicine educators, 5 residents and 5 faculty members	PUMI: Eligible for all procedures in family medicine	Global Procedural Skills Evaluation Form, 4-point scale, amount of assistance is documented ranging from significant guidance is provided to performed independently; communication skills etc. are included; Student's self-assessment is included; Difficulty of the procedures is rated as well	Not specified	Not required	Not specified	Low stakes examination (formative feedback)
Swift et al. (2013)* mO-S3	USA	Physiotherapy department	12 undergraduate 1st year physiotherapy students	PSMI: Examination skills in musculoskeletal physiotherapy (shoulder tests)	Checklist for a musculoskeletal OSCE station; 6 items checklist (5 dichotomous items and 1 ordinal item)	6 minutes	Simulation patients with 2 hours of supervised training and 1 week of independent training	Clinical instructors (2 - 20 years of experience)	Low stakes examination (mid-term)
Yudkowsky et al. (2004) HTTPE	USA	University Medical Centre	369 medical students (2nd year)	PSMI: Head to toe physical examination	138 item checklist; three-point scale (0 = incorrect, 1 = correct after prompt, 2 = correct without prompting); Test duration: 2 h; high stakes summative assessment or low stakes formative assessment	2 hours (45 minutes unprompted exam, remaining 1:45 hours are used for scoring, feedback, and teaching)	Trained patient instructors with 25 hours of training	Trained patient instructors with 25 hours of training	High stakes summative assessment and low stakes formative assessment

AMPE: Assessment of Musculoskeletal Physical Examination Skills Checklist; GPSE: Global Procedural Skills Evaluation Form; HTTPE: Head to Toe Physical Examination; mO-S3: mOSCE-Station 3 checklists; PhyES: Physical Examination Skills Checklist; PES-C: Pelvic Examination Skills Checklist; PES-R: Pelvic Examination Skill Rating Scale; PSMI: Procedure Specific Measurement Instrument; PUMI: Procedure Unspecific Measurement Instrument

** Swift et al. (2013): It was only possible to use data from a small pilot study. The follow up study evaluated a 6 station OSCE. Single values for a specific scale were not available.*

Two studies were included that reported the internal consistency of two different assessments. Swift et al. (2013) reported an internal consistency between α = 0.31 (video examiner) and α = 0.55 (onsite examiner) for the mO-S3. They calculated the internal consistency of a 6 station OSCE. The statistical method used to calculate the internal consistency was Cronbach's alpha. Boulet et al. (2004) reported an internal consistency for the OMT between 0.83 (Case 1: low back pain) and 0.97 (Case 3: asthma). All internal consistency estimates are presented in Figure 2.

Six studies were included that reported the inter-rater reliability of six assessments. Beran et al. (2012) evaluated four different procedures using the AMPE. Inter-rater reliability ranged between 0.27 (95%CI: 0 to 0.56) for the physical examination of trauma patients to 0.77 (95% CI: 0.46 to 0.9) for a physical examination of the knee.

Herbers et al. (2003) investigated the interrater reliability of students performing a specific pelvic examination with no deviations from the protocol allowed and reported kappa coefficient of κ = 0.54 for the PES-C (pelvic examination).

Ladyshewsky et al. (2000) investigated the interrater reliability for the assessment of a musculoskeletal shoulder examination using the PhyES. A kappa coefficient of κ = 0.79 was reported.

Swift et al. (2013) published an ICC of 0.77 for the interrater reliability of the mO-S3 based on the clinical competency of doctoral physical therapy students halfway through their education in musculoskeletal physiotherapy.

An interrater reliability of ICC = 0.95 for students scored on all 138 items on the head to toe examination (HTTPE) was reported by Yudkowsky et al. (2004). Lastly, Boulet et al. (2004) reported a correlation coefficient of r = 0.83 (range r = 0.06 - r = 0.93) for the interrater reliability of the OMT. The authors reported that the average difference between two raters was 2.4 points on a 0 to 30 points scale. All interrater reliability estimates are presented in Figure 3.

Intra-rater reliability was available for only one assessment. Ladyshewsky et al. (2000) published an intra-rater reliability of κ = 0.63 for the PhyES.

None of the studies included in this review evaluated the measurement error of their included assessments.

Validity

Validity of the included assessments was evaluated with regard to their content validity, criterion validity and construct validity.

Evidence for content validity was found for four assessments AMPE, PhyES, GPSE and mO-S3 (Beran et al., 2012; Ladyshewsky et al., 2000; Nothnagle et al., 2010; Swift et al., 2013). For each assessment, the authors

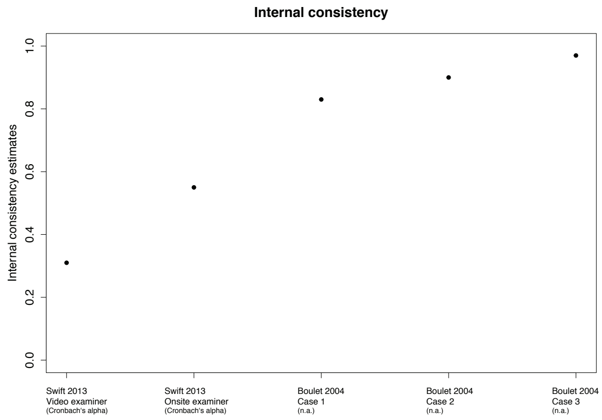

Figure 2: Internal consistency estimates.
Nb. The statistical method from Boulet et al. (2004) was not available.

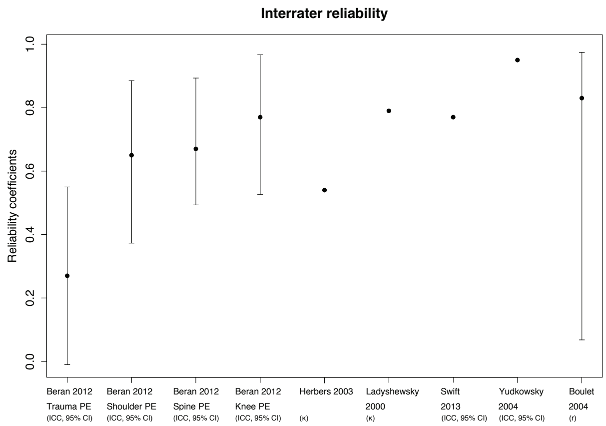

Figure 3: Interrater reliability estimates.

provided information about how their assessments were designed. All four studies used expert panels to judge the comprehensiveness and relevance of the assessment items. The size of the expert panels ranged between an unspecified number of panel members for the AMPE and mO-S3 (Beran et al., 2012; Swift et al., 2013) to 17 participants for the GPSE (Nothnagle et al., 2010). Additionally, two studies involved learners in the process of designing the assessment PhyES and GPSE (Ladyshewsky et al., 2000; Nothnagle et al., 2010) with Nothnagle et al. (2010) generating content for the GPSE through three focus groups. None of the studies within this review reported the criterion validity of their assessments. Therefore, the utility of using the assessments to predict future performance or as compared to another measure is not known.

Data regarding the construct validity was available for five assessments AMPE, OMT, PES-C, PES-R, PhyES (Beran et al., 2012; Boulet et al., 2004; Herbers et al., 2003; Ladyshewsky et al., 2000). Three studies tested the hypotheses whether their assessments could discriminate performance between individuals with more experience or less experience. Beran et al. (2012) reported that years of training had no significant influence on the total score of the AMPE. Ladyshewsky and colleagues found in their study that licenced physiotherapists performed significantly better on the PhyES than fourth year undergraduate students. Lastly, Herbers et al. (2003) presented the evidence that learners in a training group scored significantly higher than learners without a specific training ($p< 0.001$) on the PES-C. Two studies reported correlations between the included assessments and the other established assessments as evidence for construct validity. Herbers et al. (2003) reported an agreement of $K = 0.66$ between their checklist for a pelvic examination (PES-C) and a global rating scale for this procedure (PES-R). Boulet et al. (2004) reported that the OMT instrument correlated with biomedical knowledge indicators ($r = 0.47$) and global patient assessment ($r = 0.46$).

Methodological quality of assessments

Methodological quality of the included assessments was low to moderate. Methodological quality was appraised with 20 standards of the SEQAM. The assessment that was appraised as fulfilling the most standards was the AMPE. Ten of the 20 standards were appraised as fulfilled. The mO-S3 was evaluated as fulfilling the least standards (7 standards were classified as satisfied). All standards are presented in Table 4.

DISCUSSION

The discussion is divided into the following sections: 1) summary of main results, 2) methodological quality of the assessments, 3) potential biases in the review process, and 4) agreements and disagreements with other studies.

Summary of main results

This systematic review synthesised relevant literature relating to the current knowledge of assessments for procedural skills in physiotherapy education. Following a systematic search, eight assessments for procedural skills were identified that can be used in physiotherapy education. Six of the assessments were designed for a specific procedure and were validated for diagnostic or evaluative procedures. Two assessments (GPSE and OMT) were considered useful for the evaluation of more than one procedure and can be used to evaluate procedural competence of therapeutic interventions.

The GPSE was classified as representing the highest level of Miller's framework of assessments (Miller, 1990) and can be used as a workplace based assessment, which is the 'Does' level in Miller's pyramid. All the remaining assessments were classified as representing the 'Shows how' level, because they were all based in a simulated environment and no direct evidence was available to evaluate whether the behaviour of the learners actually changed.

In terms of internal consistency, the best performing assessment, (OMT), had a value above 0.70, while the other assessment reporting internal consistency (the mO-S3) had lower estimates. These lower values of the mO-S3 might be explained by the method to calculate internal consistency which was used by Swift et al. (2013). They calculated internal consistency with regard to a 6 station OSCE, with stations designed to measure competence in musculoskeletal physiotherapy. However, the content of the stations varied to some extent. This conflicts with the stance of Cortina (1993) who stated that when internal consistency is measured, the set of test items should form a reflective model, that is, 'all items are a manifestation of the underlying construct' (Mokkink et al., 2009, p. 24). It could be argued that the stations and test items of the OSCE devised by Swift et al. (2013) did not measure the same construct (e.g., diagnostic, interventional or communication competence) or that they measured different aspects of one construct. This could explain the lower internal consistency estimates of the mO-S3.

Six of the included assessments reported inter-rater reliability. The highest estimate was reported for the HTTPE (ICC: 0.95). The AMPE and the PES-C were evaluated as having moderate to low inter-rater reliability because estimates were below 0.70. There are a number of methodological issues that may have affected the reliability. For the PES-C, Herbers et al. (2003) calculated their reliability scores based on a subset of their items (i.e., only data of 7 of the 29 items of the PES-C were used). Additionally, the study used audiotapes to calculate the reliability between the two raters. With regard to a checklist that aims to evaluate procedural skills, important issues may have been missed, which can only be detected visually. Therefore, only such items as: 'Asks if patient wants mirror to watch examination' were evaluated with regard to their reliability. In relation to the AMPE, three out of the total of four different assessments scored around or above the 0.7-margin. Only the AMPE assessment of a physical examination of trauma patients scored considerably lower ($ICC = 0.27$). Beran et al. (2012) reported that considerable disagreement was present between the raters. One rater scored consistently higher than the two other raters. In an attempt to improve the reliability, the scores of three raters were averaged and compared with an external rating. This method resulted in increased interrater reliability scores ($ICC = 0.51$).

Table 4: Methodological quality of included assessments.

Standards for evaluating the quality of assessment methods	Beran 2012 (AMPE)	Boulet 2004 (OMT)	Herbers 2003 (PES-C&R)	Ladyshewsky 2000 (PhyES)	Nothnagle 2010 (GPSE)	Swift 2013 (mO-S3)	Yudkowsky 2004 (HTTPE)
Reliability							
1. Reliability indicators	☺	☺	☹	☺	☹	☺	☺
2. Inter- and Intra-rater reliability	☹	☹	☹	☺	☹	☹	☹
3. High-stakes decisions	☹	☹	☹	☹	☹	-	☹
Level of evidence (A, B, C or NR)	C	C	NR	B	NR	C	C
Validity							
1. Interpretation of results	☺	☺	☺	☺	☺	☹	☺
2. Selection of content	☺	☹	😐	☺	☺	☺	😐
3. Unintended consequences	☺	☺	☺	☺	😐	☺	☺
4. Agreement between a single expert and consensus ratings	☺	☹	☹	☹	☹	☹	☹
5. Subjective judgment	☹	☹	☹	☹	☹	☹	☹
Level of evidence (A, B, C or NR)	B	NR	NR	C	NR	NR	NR
Ease of use							
1. Daily practice	☹	☹	😐	☹	☺	☹	☺
2. Special set up	☺	☺	☺	☺	☺	☺	☺
3. Duration	☺	☺	😐	☹	😐	☺	☹
Level of evidence (A, B, C or NR)	B	B	C	C	B	B	B
Resources required							
1. Additional resources	☺	☺	☺	☺	☺	☺	☺
2. Training requirements	☹	☹	☹	☹	😐	☹	☹
3. Additional persons	☹	☹	☹	☹	☺	☹	☹
Level of evidence (A, B, C or NR)	C	C	C	C	B	C	C
Ease of interpretation							
1. Interpretation of individual scores	☺	☺	☺	😐	☺	☹	☺
2. Normative data	☺	☹	☺	☹	☹	☹	☹
3. Individual to group performance.	☹	☹	☹	☹	☹	☹	☹
Level of evidence (A, B, C or NR)	B	C	B	NR	C	NR	C
Educational impact							
1. Positively affect individual learners	☹	☹	☺	☹	☹	☹	☺
2. Positively affect programme curriculum	☹	☹	☹	☹	☹	☹	☹
3. Provide useful results	😐	😐	😐	😐	☺	😐	☺
Level of evidence (A, B, C or NR)	NR	NR	C	NR	C	NR	B

A level of evidence A was assigned when all standards in one dimension were met. A level of B was assigned when one standard was not met. A level of C was appraised when two standards were not met and NR was assigned when more than two standards were not met. ☹: Standard not met; ☺: Standard met; 😐: Unclear; -: Standard not applicable

Only the PhyES evaluated the intra-rater reliability, reporting a moderate agreement ($\kappa = 0.63$). These findings should be interpreted with caution due to the very small sample (six encounters over two occasions during a two-week period).

When a new assessment is developed, users require reassurance that the instrument is comprehensive and relevant. This might be assured by using experts to comment on or generate the content of the assessment (Mokkink et al., 2009). Furthermore, the proposed assessment should match the target population with regard to focus and detail, and one way of assuring this is to recruit potential participants and discuss the assessment with them. However, only the PhyES (Ladyshewsky et al., 2000) and the GPSE (Nothnagle et al., 2010) included students into the design of the assessments. Nothnagle et al. (2010) also used a more robust development process, including focus groups, to construct their assessment (GPSE), which may make it more likely that this assessment is comprehensive and consists of relevant items.

Evidence of construct validity was found for four assessments (PES-C, PES-R, PhyES and OMT). It has been established that learners should improve execution of a procedure in response to the level of experience and increased amounts of practice (Brydges, Carnahan, Backstein, & Dubrowski, 2007). Specifically, the PES-C and the PhyES were able to differentiate between learners with different levels of experience; however, this was not established for the AMPE.

Methodological quality of assessments

Methodological quality of assessments was evaluated with the SEQAM, which is based on the utility index of Van Der Vleuten (1996). The author argued that the appraisal of assessment methods in health professions education should consider more than traditional measurement properties (i.e., reliability and validity). Within his utility index he stressed the importance of the acceptability, the educational impact and the cost effectiveness of an assessment. The educators should take this information into account when context specific decisions about assessments are made (Van Der Vleuten & Schuwirth, 2005). Similarly, the SEQAM critically evaluates six dimensions: reliability, validity, ease of use, resources required, ease of interpretation and educational impact.

Overall, the methodological quality of the included assessments was low to moderate (fulfilling between 6 and 10 standards). No assessment was appraised as having no risk of bias. No study fulfilled all educational standards of the SEQAM. The assessment that was appraised as fulfilling the most standards was the AMPE with 10 of the 20 standards fulfilled. The mO-S3 was evaluated as fulfilling the least standards (6/20). The remaining assessments ranged between seven to nine standards fulfilled. One reason for this moderate quality of evidence was that it was derived from only a single study for each assessment. Therefore, it was not possible to complete some standards (e.g., the item ‘positively affects programme curriculum’ can only be awarded if at least two studies present the evidence).

A discrepancy existed between the assessment and the standard ‘training requirements’. The standard sets the benchmark for training time to one hour, in order to reduce the required resources. In contrast, most of the researchers spent considerably more time in the training of faculty members and standardised patients, with Ladyshewsky et al. (2000) spending up to 30 hours in the training of their assessors. This is not viable in an educational programme, and therefore, finding a reasonable balance between those extremes will be a challenge for further work.

Within the ‘non-traditional’ categories of measurement properties (e.g., non-psychometric properties), it was noted that five assessments were classified as ‘relatively easy to use’ because they required little specialist set up and time to evaluate (Beran et al., 2012; Boulet et al., 2004; Nothnagle et al., 2010; Swift et al., 2013; Yudkowsky et al., 2004). However, only the GPSE was appraised as also requiring few resources (Nothnagle et al., 2010). This could be important for educators when they need assessments in their daily practice, which are easy to set up and use.

Potential biases in the review process

Only one study for each assessment was identified; hence, limiting generalisability and rendering it impossible to perform a meta-analysis. Findings have therefore been presented narratively. Furthermore, sample size may affect findings, only three studies evaluated their assessments with considerable sample sizes. Boulet et al. (2004), Herbers et al. (2003), and Yudkowsky et al. (2004) used at least 70 participants in their studies. The remaining studies recruited considerably fewer (< 25) participants, which again may limit generalisability and may have caused imprecision of the effect estimates.

A cut off value of 0.7 was used for the measurement properties of internal consistency and inter-rater reliability and intra-rater reliability (Terwee et al., 2007). While other authors use different cut off values (e.g., 0.85 cut off) (Weiner and Stewart (1998), the more moderate interpretation was selected as 0.85 may be too high to be useful in practical settings (Streiner, Norman, & Cairney, 2014). An acceptable reliability standard should be chosen with regard to a specific situation. In high stake examinations (i.e., tests with serious consequences for the tester in situations such as education or certification (Sackett, Schmitt, Ellingson, & Kabin, 2001)), higher reliability is required as compared to a low stakes examinations (i.e., tests without serious consequences for the learner).

A further potential bias in this review is that the SEQAM grading of the methodological quality of assessment was modified. Swing et al. (2009) originally suggested an overall recommendation (i.e., class of evidence) based on the evidence levels provided for each dimension. We decided against the use of an overall score because firstly, in our view, scores should only be combined when they are unidimensional (i.e., the same attribute of the object ‘methodological quality’ should be measured with different sub-categories) and evidence for unidimensionality was not available for SEQAM; secondly, the use of summary scores might lead to biased estimates in systematic reviews and meta-analysis (da Costa, Hilfiker, & Egger, 2013; Juni, Altman, & Egger, 2001). Therefore, we decided to omit the overall recommendations and present relevant methodological aspects individually.

Agreements and disagreements with other studies or reviews

Four recent systematic reviews were identified that reported the assessment of procedural skills in health professions education (Bould, Crabtree, & Naik, 2009; Jelovsek et al., 2013; McKinley et al., 2008; Morris et al., 2012).

In general, these reviews focussed on medical education and few assessments relevant for use by allied health professions were identified. For example, of the assessments evaluated in this review, only the OMT scale was identified by McKinley and colleagues. The remaining assessments were not discussed in other reviews. Existing reviews do however agree that there is a lack of assessments for procedural skills in allied health profession. In contrast, a considerably greater number of assessments are available for use in medical education: McKinley et al. (2008) included 85 different scales in their review of assessments used in medical education. Our findings were similar to those of Jelovsek et al. (2013), who found that there was limited reporting of measurement properties. Bould et al. (2009) suggested that procedure unspecific assessments tended to miss errors in safety issues. We were not able to comment as only two procedure unspecific assessments were included in this review, and this is therefore an area where uncertainty remains and further work is required.

CONCLUSION AND IMPLICATIONS

Following this systematic review, it was not possible to recommend a single assessment of procedural skills in physiotherapy education; all the assessments we identified have elements of strengths and weaknesses. Therefore, evaluators should use existing tools carefully when evaluating the procedural performance of physiotherapy students. Most assessments we identified were developed for use within the speciality of musculoskeletal physiotherapy and these could be integrated into educational practice. There is, however, a need to develop new assessments to allow valid and reliable assessments of the broader spectrum of physiotherapeutic practice in other specialities (e.g., neurological practice and respiratory practice). When assessments are selected or developed, faculty members should carefully consider issues such as the usefulness and possible interpretation of the findings as well as the more well established focus on measurement properties such as validity and reliability. This may help prevent neglect of issues of importance to relevant stakeholders. Future studies aiming to design new assessments should involve all stakeholders in the design of the content, use and scoring of the assessment. Furthermore, the construct(s) to be measured should be clearly defined.

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“Transfer“

Gruppe (group) 1A

Vorbereitung (preparation)

Aufgabe (task)	Type cue	Imagery cue
Allgemeine Information (general information)	Kollaboration (collaboration)	Stellen Sie sicher, dass der Patient sich bei jedem Schritt sicher fühlt. (Make sure the patient feels safe during each step of the procedure)
	Kollaboration (collaboration)	Fragen Sie den Patienten an den Endpositionen jeweils kleine Gewichtsverlagerungen durchzuführen, um das bestmögliche Gleichgewicht zu finden. (Ask the patient to perform small weight shifts at the end positions to find the best possible balance)
	Kognitiv (cognitive)	Die Gewichtsverlagerungen sind die Suche nach einem Punkt an dem der Patient sich im Gleichgewicht befindet. Wenn dieser Punkt gefunden worden ist, dann fällt es dem Patienten leichter die Bewegungen zu kontrollieren. (The weight shifts are the search for a point where the patient is in equilibrium. Once this point has been found, it is easier for the patient to control the movement)

Kognitiv: Denken und Entscheiden

Kollaboration: Zusammenarbeiten

Kinästhetik: Fühlen und Bewegen

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Schritt 1 (step 1)

Aufgabe (task)	Type cue	Imagery cue
Der Patient sitzt auf der Bank und wird aufgefordert, sich zu seiner stärkeren Seite zu drehen. (The patient sits on the bench and is asked to turn to his/her stronger side)	Kollaboration (collaboration)	Nehmen Sie sich genug Zeit, dem Patienten die Prozedur zu erklären. (Take enough time to explain the procedure to the patient)
	Kinästhetik (kinaesthetic)	Platzieren Sie Ihre Hände auf dem Becken und unterstützen Sie die Drehbewegung zur stärkeren Seite. (Place your hands on the pelvis and support the rotation to the stronger side)

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Schritt 2 (step 2)

Aufgabe (task)	Type cue	Imagery cue
Der Patient wird aufgefordert, das schwächere Bein auf den Boden zu platzieren (The patient is asked to place the weaker leg on the floor)	Kollaboration (collaboration)	Achten Sie darauf, dass der Patient nicht von der Bank fällt. (Make sure the patient does not fall off the bench)
	Kinästhetik (kinaesthetic)	Stabilisieren Sie die schwächer Hüfte des Patienten und verhindern Sie, dass der Patient zur Seite fällt, wenn er sein Knie auf den Boden stellt. (Stabilise the patient's weaker hip and prevent the patient from falling to the side when he puts his knee on the floor)
	Kollaboration (collaboration)	Wenn Sie das Gefühl haben, dass Sie und der Patient stabil sind, dann bitten Sie den Patienten sein Gewicht auf das Knie zu verlagern. (If you feel that you and the patient are stable, ask the patient to shift his/her weight towards the knee)
	Kollaboration (collaboration)	Es ist wichtig, dass Sie einen stabilen Stand haben und mit dem Patienten zusammen bewegen. (It is important that you have a stable position and move together with the patient)

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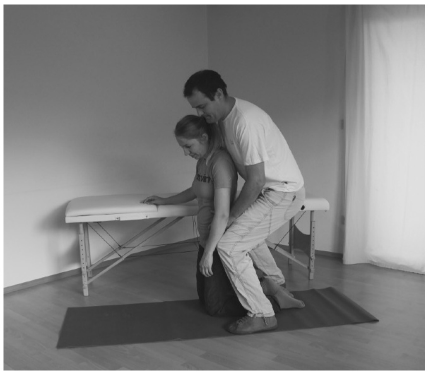
Schritt 3 (step 3)

Aufgabe (task)	Type cue	Imagery cue
Der Patient platziert sein stärkeres Knie auf dem Boden und befindet sich im Kniestand (The patient places his/her stronger knee on the floor and is in a knee-standing position)	Kollaboration (collaboration)	Fragen Sie den Patienten eine Gewichtsverlagerung auf das schwächere Knie durchzuführen und das stärkere Knie auf den Boden zu stellen. (Ask the patient to shift weight towards the weaker knee and place the stronger knee on the floor)
	Kinästhetik (kinaesthetic)	Fühlen Sie ob der Patient Gewicht auf sein schwächeres Knie verlagert. (Feel if the patient is shifting weight towards his weaker knee)
	Kinästhetik (kinaesthetic)	Kontrollieren Sie die Hüftextension des Patienten mit Ihren Knien. (Control the hip extension of the patient with your knees)
	Kollaboration (collaboration)	Geben Sie ausreichend Unterstützung, so dass der Patient anfangen kann das stärker Bein zu bewegen. (Provide sufficient support so that the patient can begin to move the stronger leg)



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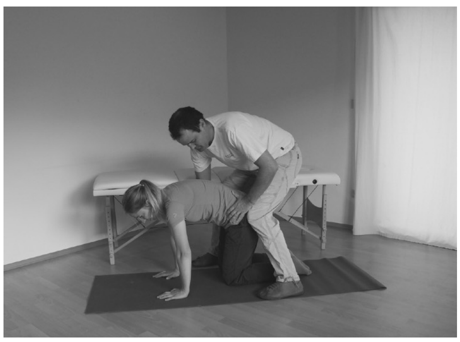
Schritt 4 (step 4)

Aufgabe (task)	Type cue	Imagery cue
Der Patient soll beide Arme auf dem Boden platzieren, so dass er sich im 4-Fussstand befindet. (The patient should place both arms on the floor so that he is in a 4-foot position)	Kognitiv (cognitive)	Falls der Patient im Kniestand viel Unterstützung benötigt hat, stellen Sie sich darauf ein, auch in dieser Situation ausreichend zu unterstützen. (If the patient required a lot of support in the knee-standing position, be prepared to provide sufficient support in this situation as well)
	Kinästhetik (kinaesthetic)	Unterstützen Sie das nach vorne Beugen des Patienten. Unterstützung geben Sie am Rumpf (z.B. Sternum) und mit Ihren Knien an den Hüften des Patienten. (Support the forward flexion of the patient. Support the trunk (e.g. sternum) and the hips of the patient with your knees)
	Kinästhetik (kinaesthetic)	Kontrollieren und stabilisieren Sie die schwache Schulter des Patienten. Fühlen Sie wie viel Muskelaktivität der Patient generiert.



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Schritt 5 (step 5)

Aufgabe (task)	Type cue	Imagery cue
Der Patient wird aufgefordert sich auf eine Seite zu setzten. (The patient is asked to sit on one side)	Kognitiv (cognitive)	Treffen Sie die Entscheidung über die schwächere oder über die stärkere Seite zu gehen. Mögliche Gründe für die stärkere Seite sind: Schmerzen, deutliche Rumpf oder Schulter Instabilität (Subluxation) oder Sie kennen den Patienten nicht ausreichend. (Make the decision to go over the weaker or the stronger side. Possible reasons for the stronger side are: Pain, significant trunk or shoulder instability (subluxation) or you do not know the patient sufficiently)
	Kinästhetik (kinaesthetic)	Kontrollieren Sie die Gewichtsverlagerung mit Ihren Knien. (Control the weight shift with your knees)
	Kinästhetik (kinaesthetic)	Eine Hand wird auf dem Rumpf platziert (z.B. Sternum), um die Belastung auf die schwächere Schulter zu reduzieren. (A hand is placed on the trunk (e.g. sternum) to reduce the load on the weaker shoulder)
	Kinästhetik (kinaesthetic)	Der Patient rutscht langsam über Ihre Beine auf den Boden. (The patient slowly slides over your legs to the floor)
	Kinästhetik (kinaesthetic)	Platzieren Sie Ihren Fuss unter dem Patienten. Falls die Bewegung zu schnell ist, wird er auf dem Fuss landen. (Place your foot under the patient. If the movement is too fast, the patient will land on the foot)

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Schritt 6 (step 6)

Aufgabe (task)	Type cue	Imagery cue
Der Patient wird instruiert sich auf die Matte zu legen (The patient is instructed to lie down on the mat)	Kollaboration (collaboration)	Instruieren Sie eine gleichmässige Bewegung (Instruct an even movement)Instruct an even movement.
	Kinästhetik (kinaesthetic)	Eine Hand wird auf dem Rumpf platziert (z.B. Sternum), um die Belastung auf die schwächere Schulter zu reduzieren. (A hand is placed on the trunk (e.g. sternum) to reduce the load on the weaker shoulder)
	Kinästhetik (kinaesthetic)	Fühlen Sie ob die schwächere Schulter stabil ist. Falls sie nicht stabil ist, führen Sie den Patienten auf den Boden und platzieren Sie ihn auf dem Rücken. (Feel if the weaker shoulder is stable. If it is not stable, guide the patient to the floor and place the patient on the back)

LEArN Trial

Schritt 7 (step 7)

Aufgabe (task)	Type cue	Imagery cue
Der Patient wird instruiert den Rumpf aufzurichten, den Ellbogen zu belasten und den Arm zu strecken. (The patient is instructed to erect the trunk, to load the elbow and to extend the arm)	Kollaboration (collaboration)	Nehmen Sie sich genug Zeit, dem Patienten die Prozedur zu erklären. (Take enough time to explain the procedure to the patient)
	Kognitiv (kinaesthetic)	Gehen Sie über die selbe Seite hoch über die Sie runtergekommen sind. Gründe für die stärkere Seite sind: Schmerzen oder Instabilität (Get up over the same side that you came down from. Reasons for the stronger side are: Pain or instability)
	Kinästhetik (kinaesthetic)	Kontrollieren und unterstützen Sie den Rumpf mit einer Hand. (Check and support the trunk with one hand)
	Kinästhetik (kinaesthetic)	Kontrollieren und unterstützen Sie die Schulter mit einer Hand. (Check and support the shoulder with one hand)

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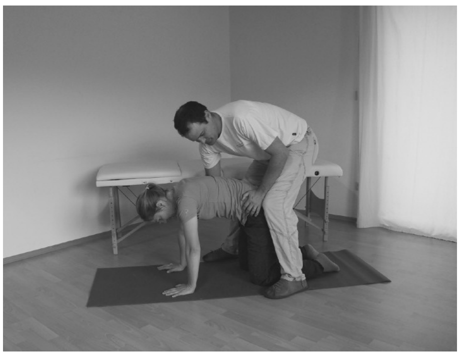
Schritt 8 (step 8)

Aufgabe (task)	Type cue	Imagery cue
Der Patient wird instruiert in den 4-Fussstand zu kommen. (The patient is instructed to get into the 4-foot position)	Kinästhetik (kinaesthetic)	Platzieren Sie Ihre Hände auf dem Becken des Patienten. Oder platzieren Sie eine Hand auf dem Rumpf falls dieser Hilfe benötigt. (Place your hands on the patient's pelvis. Or place a hand on the trunk if required)
	Kollaboration (collaboration)	Antizipieren Sie wie die Arm- und Beinposition des Patienten ist, wenn er in dem 4 Fussstand angekommen ist. (Anticipate how the arm and leg position of the patient will be when he has arrived in the 4 foot position)
	Kollaboration (collaboration)	Platzieren Sie sich so, dass der Patient sich zwischen Ihren Beinen ist, wenn er im 4-Fussstand ist. (Position yourself so that the patient is between your legs when he/she is in the 4-foot position)
	Kollaboration (collaboration)	Instruieren Sie eine Bewegung mit Schwung und geben Sie ein klares Startsignal. (Instruct a movement with momentum and give a clear starting signal)



Schritt 9 (step 9)

Aufgabe (task)	Type cue	Imagery cue
Der Patient wird instruiert sich in den Kniestand zu bewegen. (The patient is instructed to move into a knee-standing position)	Kollaboration (collaboration)	Fragen Sie den Patienten mit seinen Händen in Richtung seiner Knie zu "gehen" bis er im Kniestand ist. (Ask the patient to "walk" with his/her hands towards his/her knees until he/she is in knee position)
	Kinästhetik (kinaesthetic)	Stehen Sie hinter dem Patienten. Ihre Knie stabilisieren die Hüften des Patienten. Falls Sie zu viel Druck spüren, kann der Patient seine Hüften nicht strecken. (Stand behind the patient. Your knees stabilise the patient's hips. If you feel too much pressure, the patient cannot extend his hips)
	Kinästhetik (kinaesthetic)	Lassen Sie anfangs eine kleine Rückwärtsbewegung des Patienten zu. Dann folgt eine Vorwärtsbewegung, wenn die Hüften gestreckt werden. (Allow a small backward movement of the patient at the beginning. This is followed by a forward movement when the hips are extended)
	Kinästhetik (kinaesthetic)	Ihre Hände stabilisieren den Rumpf. (Your hands stabilise the trunk)

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Schritt 10 (step 10)

Aufgabe (task)	Type cue	Imagery cue
Der Patient wird gefragt ein Bein aufzustellen. Der Physiotherapeut unterstützt die schwächere Hüfte. (The patient is asked to move one leg forward. The physiotherapist supports the weaker hip)	Kognitiv (cognitive)	Entscheiden Sie sich, ob sie diesen Schritt mit dem stärkeren oder schwächen Bein machen. Falls das schwächere Bein aufgestellt wird, ist die folgende Bewegung schwieriger durchzuführen. (Decide whether to perform this step with the stronger or weaker leg. If the weaker leg is used, the following movement will be more difficult)
	Kognitiv (cognitive)	Fragen Sie den Patienten, kleine Gewichtsverlagerungen in Richtung des Standbeines zu machen. Versuchen Sie einen Punkt zu finden an dem das andere Bein "frei" wird und sich bewegen kann. (Ask the patient to make small weight shifts towards the standing leg. Try to find a point where the other leg becomes "free" and can move)
	Kinästhetik (kinaesthetic)	Stehen Sie hinter dem Patienten. Ihre Knie stabilisieren die Hüften des Patienten. (Stand behind the patient. Your knees stabilise the patient's hips)

LEArN Trial

Schritt 11 (step 11)

Aufgabe (task)	Type cue	Imagery cue
Der Patient wird gefragt seinen stärkeren Arm auf die Bank zu platzieren und sich auf die Bank zu setzten. (The patient is asked to place his/her stronger arm on the bench and sit down on the bench)	Kognitiv (cognitive)	Instruieren Sie den Patienten, sich mit Schwung auf die Bank zu setzten. (Instruct the patient to sit on the bench with momentum)
	Kinästhetik (kinaesthetic)	Kontrollieren Sie ob der Patient seinen Arm benutzt, um die Bewegung zu unterstützen. (Check if the patient is using his arm to support the movement)
	Kinästhetik (kinaesthetic)	Platzieren Sie Ihre Hände auf dem Becken des Patienten und unterstützen Sie die Bewegung. (Place your hands on the patient's pelvis and support the movement)

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“Transfer

Gruppe 1C

LEArN Trial

Vorbereitung

Aufgabe (task)	**Spezifische Aufgabe (specific task)**
Allgemeine Information (general information)	Stellen Sie sicher, dass der Patient sich bei jedem Schritt sicher fühlt (Make sure the patient feels safe during each step of the procedure).
	Fragen Sie den Patienten an den Endpositionen jeweils kleine Gewichtsverlagerungen durchzuführen, um das bestmögliche Gleichgewicht zu finden (Ask the patient to perform small weight shifts at each end position to find the best possible balance).

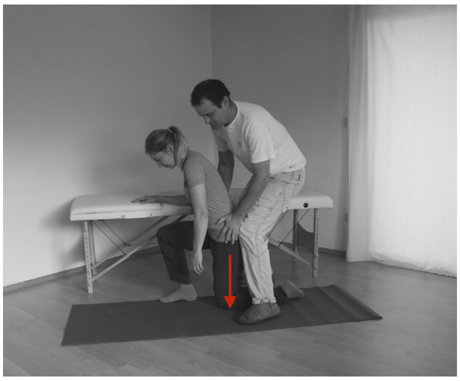
LEArN Trial

Schritt 1 (step 1)

Aufgabe (task)	Spezifische Aufgabe (specific task)
Drehen zur stärkeren Seite (Turn to the stronger side)	Nehmen Sie sich genug Zeit, dem Patienten die Prozedur zu erklären (Take enough time to explain the procedure to the patient).
	Am Ende des Schrittes sollte der Patient sich 90° gedreht haben (At the end of the step the patient should have turned 90°).

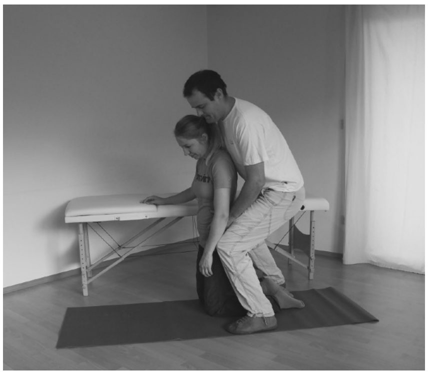
Schritt 2 (step 2)

Aufgabe (task)	Spezifische Aufgabe (specific task)
Positionswechsel in den Halbkniestand das schwächere Bein auf den Boden platzieren (Change position to semi-kneeling position and place the weaker leg on the floor.)	Stabilisieren Sie die schwächere Hüfte des Patienten und verhindern Sie, dass der Patient zur Seite fällt, wenn er sein Knie auf den Boden stellt. (Stabilise the patient's weaker hip and prevent the patient from falling to the side when he puts his knee on the floor.)
	Wenn Sie das Gefühl haben, dass der Patient stabil ist, dann bitten Sie den Patienten sein Gewicht auf das Knie zu verlagern. (If you feel that the patient is stable, ask the patient to shift his weight to the knee).
	Es ist wichtig, dass Sie sich bei der Bewegung an den Patienten anpassen und seinen Bewegungen folgen (It is important that you adapt to the patient and follow his movements).



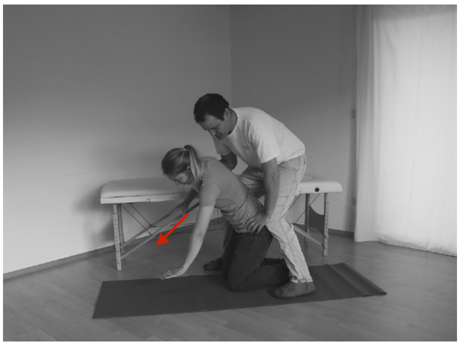
Schritt 3 (step 3)

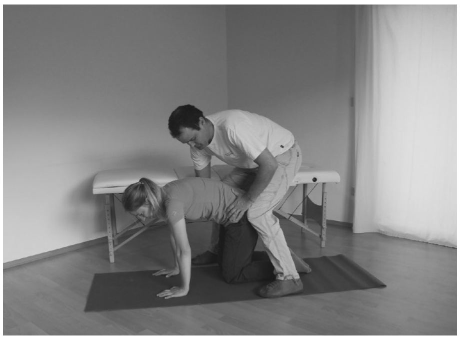
Aufgabe (task)	Spezifische Aufgabe (specific task)
Positionswechsel in den Kniestand (Change of position to the knee stand position)	Fragen Sie den Patienten eine Gewichtsverlagerung auf das schwächere Knie durchzuführen und das stärkere Knie auf den Boden zu stellen. (Ask the patient to shift weight to the weaker knee and place the stronger knee on the floor).
	Kontrollieren Sie ob der Patient Gewicht auf sein schwächeres Knie verlagert. (Check whether the patient is shifting weight to his weaker knee).
	Drücken Sie gegen die Hüfte des Patienten, um dort eine Extension zu erhalten. (Push against the patient's hip to ensure an extension).
	Der Patient muss stabil stehen, bevor er das stärkere Bein bewegen kann. (The patient must stand stable before he can move the stronger leg).



Schritt 4 (step 4)

Aufgabe (task)	Spezifische Aufgabe (specific task)
Positionswechsel in den 4-Fussstand. (Position change to the 4-foot position).	Falls der Patient im Kniestand viel Unterstützung benötigt hat, stellen Sie sich darauf ein, auch in dieser Situation ausreichend zu unterstützen. (If the patient required a lot of support in the kneeling position, be prepared to provide sufficient support in this situation as well).
	Der Patient soll sich kontrolliert nach vorne beugen. Kontrollieren Sie die Bewegung am Rumpf (z.B. am Sternum) und an den Hüften des Patienten. (The patient should bend forward in a controlled manner. Control the movement of the trunk (e.g. sternum) and hips of the patient).
	Kontrollieren und stabilisieren Sie die schwache Schulter des Patienten. Fühlen Sie wie viel Muskelaktivität der Patient generiert. (Check and stabilize the patient's weak shoulder. Feel how much muscle activity the patient generates).





Schritt 5 (step 5)

Aufgabe (task)	Spezifische Aufgabe (specific task)
Auf die Seite sitzen (Seitsitz). (Sit on the side)	Treffen Sie die Entscheidung über die schwächere oder über die stärkere Seite zu gehen. Mögliche Gründe für die stärkere Seite sind: Schmerzen, deutliche Rumpf oder Schulter Instabilität (Subluxation) oder Sie kennen den Patienten nicht ausreichend. (Make the decision to go down over the weaker or the stronger side. Possible reasons for the stronger side are: Pain, significant trunk or shoulder instability (subluxation) or you do not know the patient sufficiently).
	Kontrollieren Sie die Gewichtsverlagerung des Patienten. (Check the patient's weight shift).
	Reduzieren Sie die Belastung der schwächeren Schulter indem Sie Gewicht vom Rumpf übernehmen (z.B. vom Sternum). (Reduce the load on the weaker shoulder by taking weight from the trunk (e.g. sternum)).
	Der Patient sollte langsam in Richtung Boden rutschen. (The patient should slowly slide towards the floor).
	Sorgen Sie dafür, dass Gesäss des Patienten nicht zu schnell auf dem Boden aufkommt und weich landet. (Ensure that the patient's buttocks do not land too quickly on the floor and land softly).

Schritt 6 (step 6)

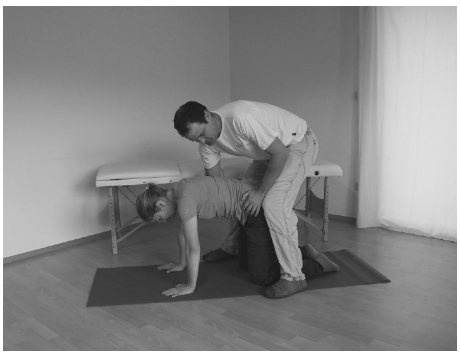
Aufgabe (task)	Spezifische Aufgabe (specific task)
Auf die Matte legen. (Lie on the mat).	Instruieren Sie eine gleichmässige Bewegung. (Instruct an even movement).
	Reduzieren Sie die Belastung auf der schwächeren Schulter indem Sie den Patienten z.B. am Sternum unterstützen. (Reduce the load on the weaker shoulder by supporting the patient e.g. at the sternum).
	Fühlen Sie ob die schwächere Schulter stabil ist. Falls sie nicht stabil ist führen Sie den Patienten auf den Boden und platzieren Sie ihn auf dem Rücken. (Feel if the weaker shoulder is stable. If it is not stable, guide the patient to the floor and place him/her on the back).

Schritt 7 (step 7)

Aufgabe (task)	Spezifische Aufgabe (specific task)
Zurück in den Seitsitz bewegen (Move back to the side seat).	Nehmen Sie sich genug Zeit, dem Patienten die Prozedur zu erklären. (Take enough time to explain the procedure to the patient).
	Gehen Sie über die selbe Seite hoch über die Sie runtergekommen sind. Gründe für die stärkere Seite sind: Schmerzen oder Instabilität. (Get up over the same side that you came down from. Reasons for the stronger side are: Pain or instability).
	Kontrollieren und unterstützen Sie den Rumpf des Patienten. (Check and support the patient's trunk).
	Kontrollieren und unterstützen Sie die Schulter des Patienten. (Check and support the patient's shoulder).

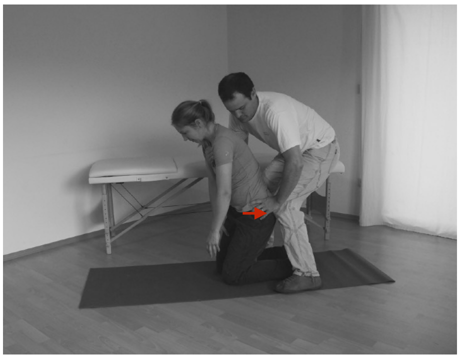
Schritt 8 (step 8)

Aufgabe (task)	Spezifische Aufgabe (specific task)
Positionswechsel in den 4-Fussstand. (Position change to the 4-foot position)	Unterstützen Sie den Patienten am Becken und am Rumpf falls Hilfe benötigt wird. (Support the patient's pelvis or trunk if help is needed).
	Antizipieren Sie wie die Arm- und Beinposition des Patienten ist, wenn er in dem 4-Fussstand angekommen ist. (Anticipate how the arm and leg position of the patient will be when he/she has arrived in the 4-foot position).
	Platzieren Sie sich so, dass sie sich über dem Patienten befinden wenn er im 4-Fussstand ist. (Position yourself so that you are above the patient when he is in the 4-foot position).
	Instruieren Sie eine Bewegung mit Schwung und geben Sie ein klares Startsignal. (Instruct a movement with momentum and give a clear starting signal).



Schritt 9 (step 9)

Aufgabe (task)	Spezifische Aufgabe (specific task)
Positionswechsel in den Kniestand (Change of position to knee stand position	Fragen Sie den Patienten mit seinen Händen in Richtung seiner Knie zu “gehen” bis er im Kniestand ist. (Ask the patient to "walk" with his hands towards his knees until he/she is in the knee standing position).
	Stehen Sie hinter dem Patienten. Stabilisieren Sie die Hüften des Patienten. Wenn der Patient zu stark nach hinten drückt, kann er seine Hüften nicht strecken. (Stand behind the patient. Stabilize the patient's hips. If the patient pushes too far back, he/she cannot extend his/her hips.)
	Lassen Sie anfangs eine kleine Rückwärtsbewegung des Patienten zu. Dann folgt eine Vorwärtsbewegung, wenn die Hüften gestreckt werden. (Allow a small backward movement of the patient at the beginning. This is followed by a forward movement when the hips are extended.
	Der Rumpf des Patienten muss stabil sein. (The patient's trunk must be stable).



LEArN Trial

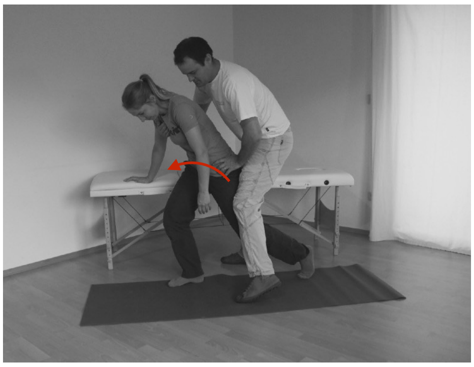
Schritt 10 (step 10)

Aufgabe (task)	Spezifische Aufgabe (specific task)
Positionswechseln in den Halbkniestand. (Change position to the semi-knee standing position).	Entscheiden Sie sich, ob sie diesen Schritt mit dem stärkeren oder schwächen Bein machen. Falls das schwächere Bein aufgestellt wird, ist die folgende Bewegung schwieriger durchzuführen. (Decide whether to perform this step with the stronger or weaker leg. If the weaker leg is used, the following movement will be more difficult).
	Stehen Sie hinter dem Patienten. Stabilisieren Sie die Hüften des Patienten. (Stand behind the patient. Stabilise the patient's hips).
	Fragen Sie den Patienten, kleine Gewichtsverlagerungen in Richtung des Standbeines zu machen. Versuchen Sie einen Punkt zu finden an dem das andere Bein “frei” wird und sich bewegen kann. (Ask the patient to make small weight shifts towards the standing leg. Try to find a point where the other leg becomes "free" and can move).

LEArN Trial

Schritt 11 (step 11)

Aufgabe (task)	Spezifische Aufgabe (specific task)
Auf die Bank setzen. (Sit on the bench).	Instruieren Sie den Patienten, sich mit Schwung auf die Bank zu setzten. (Instruct the patient to sit on the bench with momentum).
	Platzieren Sie den Arm des Patienten so, dass er bei der Bewegung mithelfen kann. (Place the patient's arm so that it can help with the movement).
	Helfen Sie dem Patienten indem sie das Becken bei der Bewegung unterstützen. (Help the patient by supporting the pelvis during movement).



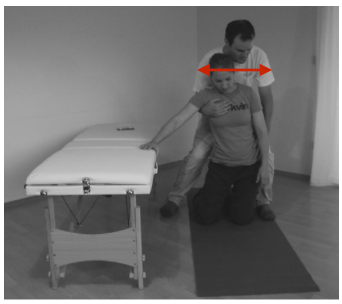
LEArN Trial

“Transfer“

Gruppe 1D

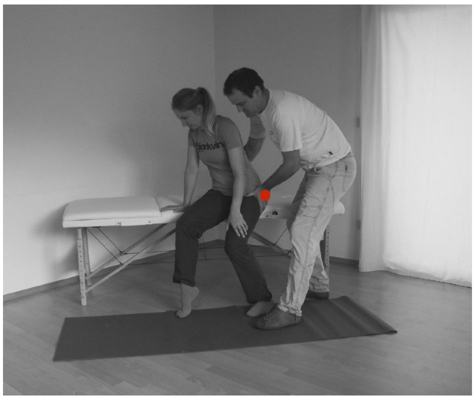
Vorbereitung (Preparation)

Aufgabe (Task)	Spezifische Aufgabe (Specific task)
Allgemeine Information (general information)	Stellen Sie sicher, dass der Patient sich bei jedem Schritt sicher fühlt. (Make sure the patient feels safe during each step of the procedure)
	Benutzen Sie ihren Körper (z.B. die Hände), um dem Patienten zu ermöglichen kleine Gewichtsverlagerungen in den Endpositionen durchzuführen. (Use your body (e.g. hands) to allow the patient to perform small weight shifts in the end positions)



Schritt 1 (step 1)

Aufgabe (Task)	Spezifische Aufgabe (Specific task)
Drehen zur stärkeren Seite (Turn to the stronger side)	Nehmen Sie sich genug Zeit, dem Patienten die Prozedur zu erklären. (Take enough time to explain the procedure to the patient)
	Platzieren Sie Ihre Hände auf dem Becken und unterstützen Sie die Drehbewegung zur stärkeren Seite. (Place your hands on the pelvis and support the rotation to the stronger side)

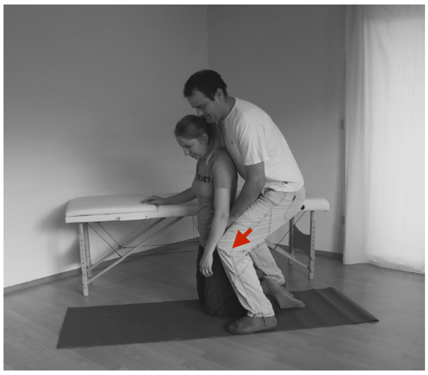


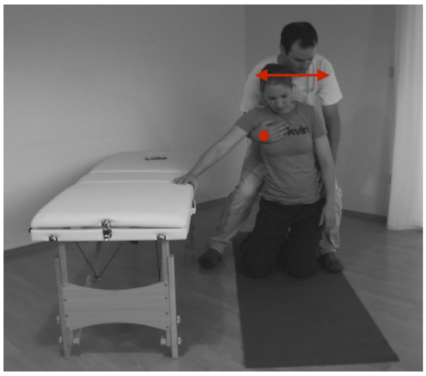
Schritt 2 (step 2)

Aufgabe (Task)	Spezifische Aufgabe (Specific task)
Positionswechsel in den Halbkniestand (das schwächere Bein auf den Boden platzieren). (Change position to semi-knee standing position (place the weaker leg on the floor))	Platzieren Sie ihr Knie lateral des Patienten und stabilisieren Sie damit seine Hüfte. (Place your knee lateral to the patient and stabilise his/her hip)
	Stellen Sie sich so hin, dass Sie fühlen, dass sie stabil stehen. Bitten Sie anschliessend den Patienten sein Bein auf den Boden zu stellen. (Position yourself, that you feel you're stable. Then ask the patient to place his leg on the floor)
	Konzentrieren Sie sich bei der Bewegung auf ihre Beine und versuchen Sie eine gleichmäßige Bewegung durchzuführen. (Concentrate on your legs as you move and try to move evenly).

Schritt 3 (step 3)

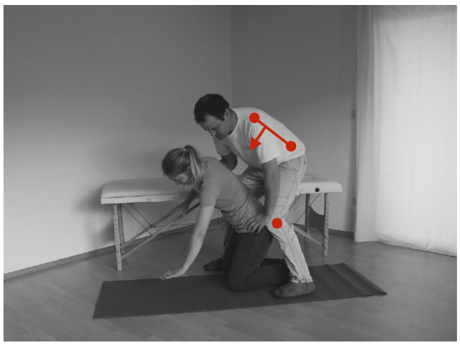
Aufgabe (Task)	Spezifische Aufgabe (Specific task)
Positionswechsel in den Kniestand. (Change of position to the knee-standing position)	Helfen Sie dem Patienten mit ihren Armen und Beinen eine Gewichtsverlagerung auf das schwächere Knie durchzuführen und das stärkere Knie auf den Boden zu stellen. (Help the patient to shift the weight towards the weaker knee (with your arms and legs) and place the stronger knee on the floor.
	Fühlen Sie ob Sie einen Druck an ihrem Knie spüren, der darauf hindeutet, dass der Patient Gewicht auf sein schwächeres Knie verlagert. (Feel if you feel pressure on your knee. This indicates that the patient is shifting weight towards his weaker knee)
	Positionieren Sie ihr Knie hinter der Hüfte des Patienten, um eine Extension zu kontrollieren. (Position your knee behind the patient's hip to control the hip extension)
	Stabilisieren Sie den Patienten mit ihrem Körper, so dass der Patient anfangen kann das stärkere Bein zu bewegen. (Stabilise the patient with your body so that the patient can start to move the stronger leg).

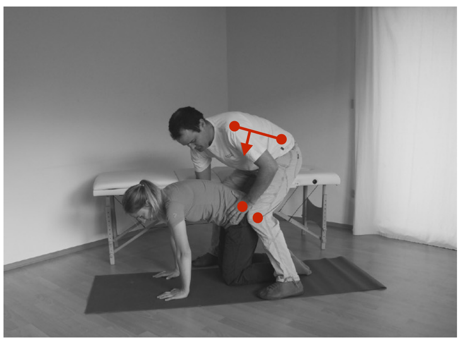




Schritt 4 (step 4)

Aufgabe (Task)	Spezifische Aufgabe (Specific task)
Positionswechsel in den 4-Fussstand. (Position change to the 4-foot position)	Falls der Patient im Kniestand viel Unterstützung benötigt hat, stellen Sie sich darauf ein, auch in dieser Situation ausreichend zu unterstützen. (If the patient required a lot of support in the knee standing position, be prepared to provide sufficient support in this situation as well)
	Benutzen Sie ihre Hände, um den Rumpf zu kontrollieren (z.B. am Sternum). Ihre Knie positionieren Sie an den Hüften des Patienten. Unterstützen Sie das nach vorne Beugen des Patienten mit ihrem Körper. (Use your hands to control the trunk (e.g. sternum). Position your knees next to the patient's hips. Support the forward bending of the patient with your body)
	Fühlen Sie mit ihren Händen wie viel Muskelaktivität der Patient an seiner Schulter generiert. Benutzen Sie ihre Hände, um die Schulter zu stabilisieren.





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Schritt 5 (step 5)

Aufgabe (Task)	**Spezifische Aufgabe (Specific task)**
Auf die Seite sitzen (Seitsitz). (Sitting on the side (side seat))	Treffen Sie die Entscheidung über die schwächere oder über die stärkere Seite zu gehen. Mögliche Gründe für die stärkere Seite sind: Schmerzen, deutliche Rumpf oder Schulter Instabilität (Subluxation) oder Sie kennen den Patienten nicht ausreichend. (Make the decision to go over the weaker or the stronger side. Possible reasons for the stronger side are: Pain, significant trunk or shoulder instability (subluxation) or you do not know the patient sufficiently)
	Benutzen Sie ihre Knie um die Gewichtsverlagerung zu kontrollieren. (Use your knees to control the weight shift)
	Platzieren Sie ihre Hand auf dem Rumpf (z.B. auf dem Sternum), um die Belastung auf die schwächere Schulter zu reduzieren. (Place your hand on the trunk (e.g. on the sternum) to reduce the load on the weaker shoulder)
	Platzieren Sie ihre Beine so, dass der Patient langsam über sie in Richtung Boden rutschen kann (Place your legs so that the patient can slowly slide over them towards the floor)
	Platzieren Sie Ihren Fuss unter dem Patienten. Falls die Bewegung zu schnell ist, wird er auf ihrem Fuss landen. (Place your foot under the patient. If the movement is too fast, he/she will land on your foot)

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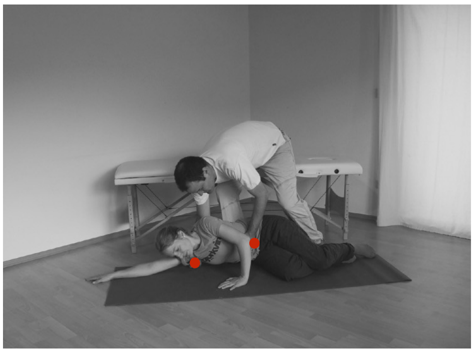
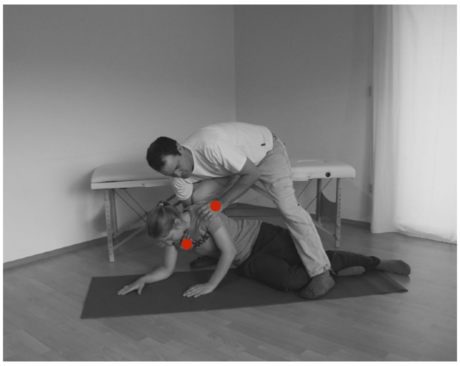
Schritt 6 (step 6)

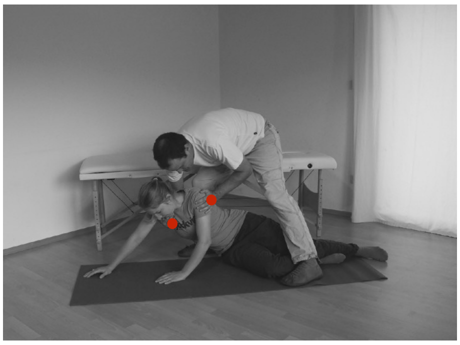
Aufgabe (Task)	**Spezifische Aufgabe (Specific task)**
Auf die Matte legen (Lie on the mat)	Instruieren Sie eine gleichmässige Bewegung. (Instruct an even movement)
	Platzieren Sie eine Hand auf dem Rumpf (z.B. Sternum), um die Belastung auf die schwächere Schulter zu reduzieren. (Place one hand on the trunk (e.g. sternum) to reduce the load on the weaker shoulder)
	Fühlen Sie mit ihrer Hand ob die schwächere Schulter stabil ist. Falls sie nicht stabil ist, führen Sie den Patienten mit ihren Armen auf den Boden und platzieren Sie ihn auf dem Rücken. (Feel with your hand if the weaker shoulder is stable. If it is not stable, guide the patient to the floor with your arms and place the patient on the back)



Schritt 7 (step 7)

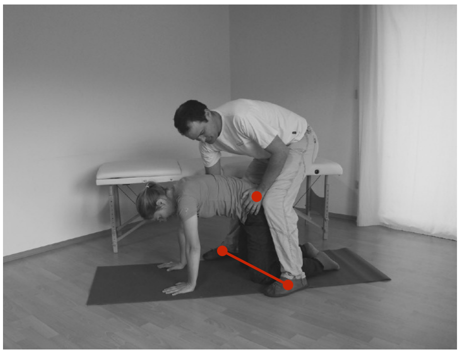
Aufgabe (Task)	Spezifische Aufgabe (Specific task)
Zurück in den Seitsitz bewegen. (Move back to the side seat)	Nehmen Sie sich genug Zeit, dem Patienten die Prozedur zu erklären (Take enough time to explain the procedure to the patient)
	Gehen Sie über die selbe Seite hoch über die Sie runtergekommen sind. Gründe für die stärkere Seite sind: Schmerzen oder Instabilität. (Get up over the same side that you came down from. Reasons for the stronger side are: Pain or instability)
	Benutzen Sie ihre Hände, um den Rumpf zu unterstützen. (Use your hands to support the trunk)
	Benutzen Sie ihre Hände, um die Schulter zu unterstützen. (Use your hands to support the shoulder)





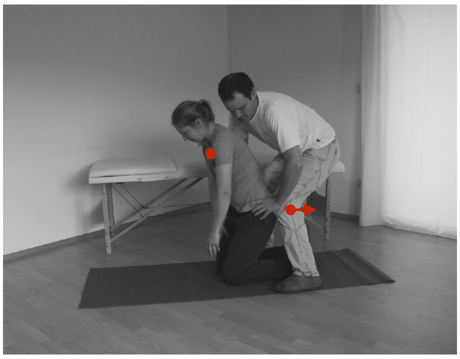
Schritt 8 (step 8)

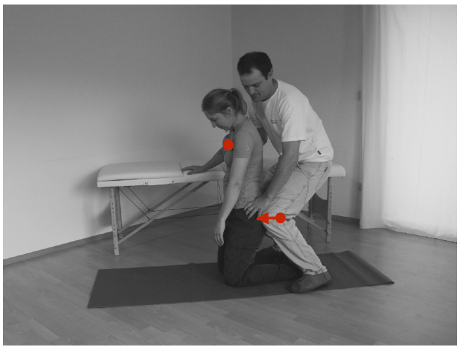
Aufgabe (Task)	Spezifische Aufgabe (Specific task)
Positionswechsel in den 4-Fussstand. (Position change to the 4-foot position)	Platzieren Sie Ihre Hände auf dem Becken des Patienten. Oder platzieren Sie eine Hand auf dem Rumpf falls dieser Hilfe benötigt. (Place your hands on the patient's pelvis. Or place a hand on the trunk if required)
	Antizipieren Sie wie ihre Arm- und Beinposition ist, wenn der Patient in dem 4 Fussstand angekommen ist. (Anticipate how your arm and leg position will be when the patient has arrived in the 4 foot position)
	Platzieren Sie sich so, dass der Patient sich zwischen Ihren Beinen befindet, wenn er im 4-Fussstand ist. (Position yourself so that the patient is between your legs when he or she is in the 4-foot position)
	Bevor Sie anfangen sich zu bewegen, geben Sie ein klares Startsignal. (Before you begin to move, give a clear starting signal)



Schritt 9 (step 9)

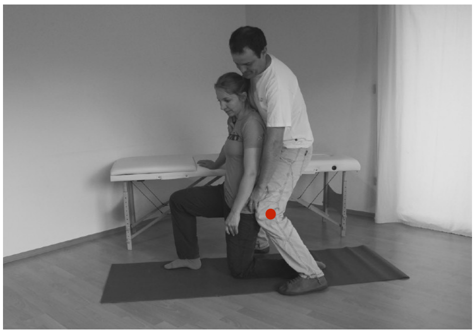
Aufgabe (Task)	Spezifische Aufgabe (Specific task)
Positionswechsel in den Kniestand (Change of position to knee-standing position)	Fragen Sie den Patienten mit seinen Händen in Richtung seiner Knie zu "gehen" bis er im Kniestand ist. (Ask the patient to "walk" with his hands towards his/her knees until he/she is in the knee-standing position)
	Positionieren Sie sich hinter dem Patienten. Ihre Knie stabilisieren die Hüften des Patienten. Falls Sie zu viel Druck an den Knien spüren, kann der Patient seine Hüften nicht strecken. (Position yourself behind the patient. Your knees stabilise the patient's hips. If you feel too much pressure on the knees, the patient cannot extend his/ her hips)
	Ihre Beine machen anfangs eine Rückwärtsbewegung mit dem Patienten. Ab einem Punkt folgt eine Vorwärtsbewegung ihrer Beine. (Your legs initially make a backward movement (together) with the patient. At one point, your legs move forward)
	Ihre Hände stabilisieren den Rumpf. (Your hands stabilise the trunk)





Schritt 10 (step 10)

Aufgabe (Task)	Spezifische Aufgabe (Specific task)
Positionswechseln in den Halbkniestand. (Change position to the semi-knee-standing position)	Entscheiden Sie sich, ob sie diesen Schritt mit dem stärkeren oder schwächen Bein machen. Falls das schwächere Bein aufgestellt wird, ist die folgende Bewegung schwieriger durchzuführen. (Decide whether to perform this step with the stronger or weaker leg. If the weaker leg is used, the following movement will be more difficult)
	Positionieren Sie sich hinter dem Patienten. Ihre Knie stabilisieren die Hüften des Patienten. (Position yourself behind the patient. Your knees stabilise the patient's hips)
	Fragen Sie den Patienten, kleine Gewichtsverlagerungen in Richtung ihres Knies zu machen. Wenn der Patient weit genug in Richtung ihres Beines geht, kann er das anderes Bein aufstellen. (Ask the patient to make small weight shifts toward the knee. If the patient moves far enough towards the knee, he can move the other leg forwards)



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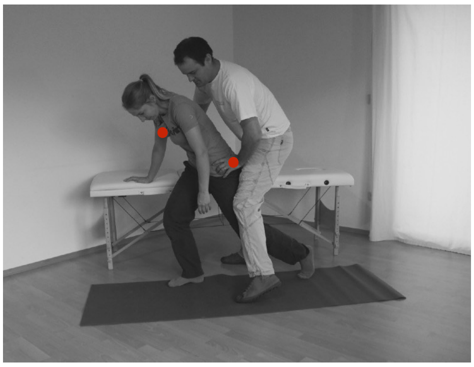
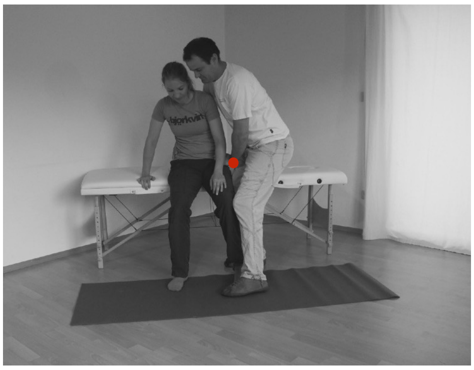
Schritt 11 (step 11)

Aufgabe (Task)	**Spezifische Aufgabe (Specific task)**
Auf die Bank setzen. (Sit on the bench)	Instruieren Sie den Patienten, sich mit Schwung auf die Bank zu setzten. (Instruct the patient to sit on the bench with momentum)
	Führen Sie mit ihrer Hand den Arm des Patienten in eine Stellung, dass er bei der Bewegung mithelfen kann. (Use your hand to move the patient's arm into a position where he/she can support the movement)
	Platzieren Sie Ihre Hände auf dem Becken des Patienten und unterstützen Sie die Bewegung. (Place your hands on the patient's pelvis and support the movement)





LEArN Trial

Vestibular rehabilitation

LEArN Trial

Gruppe (group) 2A

Dix-Hallpike Test

Vorbereitung (preparation)

Aufgabe (task)	Typ cue	Imagery cue
Allgemeine Information (general information)	Kognitiv (cognitive)	Erklären Sie dem Patienten die Prozedur. (Explain the procedure to the patient)
	Kognitiv (cognitive)	Stellen Sie einen Eimer bereit, falls dem Patienten "schlecht" wird. (Provide a bucket in case the patient gets "sick")
	Kollaborativ (collaborative)	Erklären Sie dem Patienten, dass er bei den folgenden Schritten aktiv mitbewegen soll. (Explain to the patient that he should actively participate in the following steps)

Schritt 1 (step 1)

Aufgabe (task)	Type cue	Imagery cue
Der Patient setzt sich in Langsitz-position auf die Bank (The patient sits on the bench)	Kinästhetik (kinaesthetic)	Der Therapeut steht aufrecht neben dem Patienten. (The therapist stands upright next to the patient)
	Kognitiv (cognitive)	Brillen sollten abgenommen werden. (Glasses should be removed)
	Kognitiv (cognitive)	Der pSCC* des Ohres, dass am bodennächsten ist, wird am stärksten provoziert. Der aSCC* wird aber auch provoziert. (The pSCC* of the ear that is closest to the ground is provoked the most. The aSCC* is also provoked)

*pSCC: posterior semicircular canal
*aSCC: anterior semicircular canal

Schritt 2 (step 2)

Aufgabe (task)	Type cue	Imagery cue
Der Kopf des Patienten wird 45° rotiert (in Richtung der zu testenden Seite) (The patient's head is rotated 45° (in the direction of the side to be tested))	Kinästhetik (kinaesthetic)	Manuelle Unterstützung des Kopfes (Manual support of the head)
	Kognitiv (cognitive)	Achten Sie darauf die 45° Stellung bei den folgenden Schritten beizubehalten. (Be sure to maintain the 45° position during the following steps)
	Kollaborativ (collaborative)	Sagen Sie dem Patienten, dass er ihre Arme mit einem Kreuzgriff ergreifen kann (bei Unsicherheit) (Tell the patient that he can grasp your arms (in case of uncertainty))

Schritt 3 (step 3)

Aufgabe	Typ cue	Imagery cue
Der Patient wird in die Rücklage gebracht. Das zu testende Ohr liegt unten. (The patient is placed into the supine position. The ear to be tested is below)	Visuell (visual)	Observieren der Augen des Patienten im Bezug auf Nystagmus (Dauer und Richtung) (Observe the patient's eyes in relation to nystagmus (duration and direction))
	Visuell (visual)	Das Kinn solte nach oben zeigen und der Kopf sollte über der Bank hängen (20° Extension) (The chin should point upwards and the head should hang over the bench (20° extension))
	Kinaesthetisch (kinaesthetic)	Manuelle Unterstützung des Kopfes (Manual support of the head)
	Kinaesthetisch (kinaesthetic)	Stellen Sie sich stabil (breitbeinig) hin und führen Sie den Patienten in die Rücklage. Der Patient bewegt sich "en bloc" nach unten (Stand stably (with your legs apart) and guide the patient into the supine position. The patient moves "en bloc" downwards)
	Kognitiv (cognitive)	Bei einer Läsion des pSCC "upbeat" Nystagmus, aSCC "downbeat" nystagmus" (In case of a lesion of the pSCC "upbeat" nystagmus, aSCC "downbeat" nystagmus)
	Kollaborativ (collaborative)	Fragen Sie den Patienten nach Vertigo. (Ask the patient for Vertigo)
	Kollaborativ (collaborative)	Sagen Sie dem Patienten, dass er ihre Arme mit einem Kreuzgriff ergreifen kann (bei Unsicherheit) (Tell the patient that he can grasp your arms (in case of uncertainty))

*pSCC: posterior semicircular canal
*aSCC: anterior semicircular canal

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Schritt 4 (step 4)

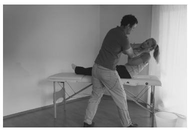
Aufgabe (task)	Type cue	Imagery cue
Der Patient wird langsam wieder in den Langsitz gebracht. (The patient is slowly brought back into a sitting position)	Kognitiv (cognitive)	Starten Sie diesen Schritt, wenn die Symptome und der Nystagmus nachgelassen haben. (Start this step when symptoms and nystagmus have subsided)
	Visual (visual)	Observieren der Augen des Patienten im Bezug auf Nystagmus (Dauer und Richtung) (Observe the patient's eyes in relation to nystagmus (duration and direction))
	Kinaesthetisch (kinaesthetic)	Manuelle Unterstützung des Kopfes (Manual support of the head)
	Kinaesthetisch (kinaesthetic)	Stellen Sie sich stabil (breitbeinig) hin und führen Sie den Patienten mit einer Bewegung ihres ganzen Körpers (Position yourself stably (with your legs apart) and guide the patient with a movement of your whole body)
	Kollaborativ (collaborative)	Fragen Sie den Patienten nach Vertigo. (Ask the patient for Vertigo)
	Kollaborativ (collaborative)	Sagen Sie dem Patienten, dass er ihre Arme mit einem Kreuzgriff ergreifen kann (bei Unsicherheit) (Tell the patient that he can grasp your arms (in case of uncertainty).

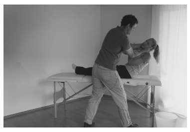
LEArN Trial

Schritt 5 (step 5)

Aufgabe (task)	Type cue	Imagery cue
Der Test wird auf der anderen Seite durchgeführt (The test is performed on the other side)	Kinästhetik (kinaesthetic)	Der Therapeut steht aufrecht neben dem Patienten. (The therapist stands upright next to the patient)
	Kognitiv (cognitive)	Brillen sollten abgenommen werden. (Glasses should be removed)
	Kognitiv (cognitive)	Der pSCC des Ohres, dass am bodennächsten ist, wird am stärksten provoziert. Der aSCC wird aber auch provoziert. (The pSCC* of the ear that is closest to the ground is provoked the most. The aSCC* is also provoked)








Canalith repositioning technique (CRT)

Vorbereitung (preparation)

Aufgabe (task)	Type cue	Imagery cue
Allgemeine Information (general information)	Kognitiv (cognitive)	Erklären Sie dem Patienten die Prozedur. (Explain the procedure to the patient)
	Kognitiv (cognitive)	Stellen Sie einen Eimer bereit, falls dem Patienten “schlecht” wird. (Provide a bucket in case the patient gets “sick”)
	Kognitiv (cognitive)	Timing: Nicht notwendig schnell durch die Positionen zu bewegen. (Timing: Not necessary to move quickly through the positions)
	Kognitiv (cognitive)	Bleiben Sie in einer Position bis die Symptome nachlassen. Falls keine Symptome anwesend sind orientieren Sie sich an der Dauer der Symptome in dem vorgegangenem Test (Stay in one position until symptoms subside. If no symptoms are present, use duration of the symptoms in the previous test as orientation)
	Kollaborativ (collaborative)	Erklären Sie dem Patienten, dass er bei den folgenden Schritten aktiv mithelfen soll. (Explain to the patient that he should actively participate in the following steps)

Schritt 1 (step 1)

Aufgabe (task)	Type cue	Imagery cue
Der Patient setzt sich in Langsitz-position auf die Bank und der Kopf wird 45° zur betroffenen Seite gedreht (The patient sits in a long sitting position on the bench and the head is turned 45° to the affected side)	Kinästhetik (kinaesthetic)	Der Therapeut steht aufrecht neben dem Patienten. (The therapist stands upright next to the patient)
	Kinästhetik (kinaesthetic)	Manuelle Unterstützung des Kopfes (Manual support of the head)

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Schritt 2 (step 2)

Aufgabe (task)	Type cue	Imagery cue
Der Patient wird in die Dix-Hallpike Position auf der betroffenen Seite gebracht (d.h. links betroffen; der Kopf ist 45° nach links gedreht) (The patient is placed in the Dix-Hallpike position on the affected side (i.e. affected on the left; the head is turned 45° to the left))	Visuell (visual)	Der Kopf sollte über der Bank hängen (in Extension) (The head should hang over the bench (in extension))
	Kinaesthetisch (kinaesthetic)	Kontrollieren Sie die Kopfposition des Patienten (45° Rotation und ~20 Extension) (Check the head position of the patient (45° rotation and ~20 extension))
	Kinaesthetisch (kinaesthetic)	Stellen Sie sich stabil (breitbeinig) hin und führen Sie den Patienten mit einer Bewegung ihres ganzen Körpers (Position yourself stably (with your legs apart) and guide the patient with a movement of your whole body)
	Kognitiv (cognitive)	Bleiben Sie in der Position bis die Symptome nachlassen (Stay in position until symptoms subside)
	Kollaborativ (collaborative)	Sagen Sie dem Patienten, dass er ihre Arme mit einem Kreuzgriff ergreifen kann (bei Unsicherheit) (Tell the patient that he can grasp your arms (in case of uncertainty))

Schritt 3 (step 3)

Aufgabe (task)	Type cue	Imagery cue
Der Kopf des Patienten wird 90° in Richtung der nicht betroffenen Seite gedreht (The patient's head is turned 90° towards the unaffected side)	Kinaesthetisch (kinaesthetic)	Halten Sie den Kopf in einer moderaten Extension (~20°) während der Drehung (Hold the head in a moderate extension (~20°) during the rotation)
	Kognitiv (cognitive)	Bleiben Sie in dieser Position bis die Symptome nachlassen (Stay in this position until symptoms subside)

Schritt 4 (step 4)

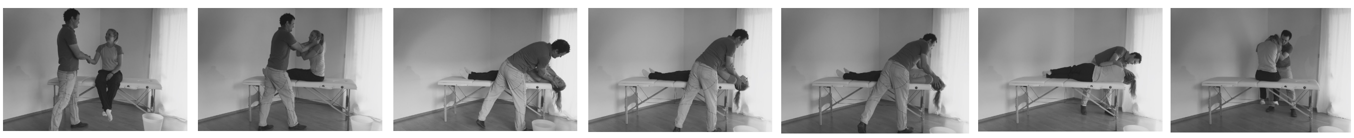
Aufgabe (task)	Type cue	Imagery cue
Der Patient rollt auf seine Seite und der Kopf schaut in Richtung Boden (The patient rolls on his side and his head points towards the floor)	Kinaesthetisch (kinaesthetic)	Der Kopf wird 45° in Richtung des Bodens gedreht (die nicht betroffene Seite ist bodennah) (The head is turned 45° towards the ground (the unaffected side is near the ground))
	Kognitiv (cognitive)	Bleiben Sie in dieser Position bis die Symptome nachlassen (Stay in this position until symptoms subside)

Schritt 5 (step 5)

Aufgabe (task)	Type cue	Imagery cue
Der Patient setzt sich langsam aufrecht hin (The patient slowly gets up)	Kinaesthetisch (kinaesthetic)	Die Drehung des Kopfes (45° in Richtung der nicht betroffenen Seite) wird beibehalten The rotation of the head (45° towards the unaffected side) is maintained)
	Kinaesthetisch (kinaesthetic)	Der Kopf wird in einer leichten Flexion eingestellt (The head is positioned in a slight flexion)
	Kinaesthetisch (kinaesthetic)	Stellen Sie sich stabil (breitbeinig) hin und führen Sie den Patienten mit einer Bewegung ihres ganzen Körpers (Position yourself stably (with your legs apart) and guide the patient with a movement of your whole body)
	Kollaborativ (collaborative)	Sagen Sie dem Patienten, dass er ihre Arme mit einem Kreuzgriff ergreifen kann (bei Unsicherheit) (Tell the patient that he can grasp your arms (in case of uncertainty))
	Kognitiv (cognitive)	Bei einigen Patienten treten die Symptome im Sitz wieder auf. (The symptoms may reappear in this position)

Schritt 6 (step 6)

Aufgabe (task)	Type cue	Imagery cue
Der Therapeut gibt "Post-procedure" Instruktionen (The therapist provides post-procedure instructions)	Kognitiv (cognitive)	Der Patient sollte eine aufrechte Position einnehmen für die nächsten 20 Minuten (The patient should maintain an upright position for the next 20 minutes)
	Kognitiv (cognitive)	Instruieren Sie dem Patienten die CRT Prozedur als Heimprogramm (Instruct the CRT procedure as a home programme)



Liberatory manoeuvre (LM)

Vorbereitung (preparation)

Aufgabe (task)	Type cue	Imagery cue
Allgemeine Information (general information)	Kognitiv (cognitive)	Erklären Sie dem Patienten die Prozedur. (Explain the procedure to the patient)
	Kognitiv (cognitive)	Die "LM" Prozedur kann anstelle des "CRT" durchgeführt werden, falls Patienten keine Extension der HWS durchführen können (The "LM" procedure can be performed instead of the "CRT" if patients are unable to extend the cervical spine.)
	Kognitiv (cognitive)	Stellen Sie einen Eimer bereit, falls dem Patienten "schlecht" wird. (Provide a bucket in case the patient gets "sick")
	Kognitiv (cognitive)	Bleiben Sie in einer Position bis die Symptome nachlassen. Falls keine Symptome anwesend sind orientieren Sie sich an der Dauer der Symptome in dem vorgegangenem Test (Stay in one position until symptoms subside. If no symptoms are present, use duration of the symptoms in the previous test as orientation)
	Kollaborativ (collaborative)	Erklären Sie dem Patienten, dass er bei den folgenden Schritten aktiv mithelfen soll. (Explain to the patient that he should actively participate in the following steps)

Schritt 1 (step 1)

Aufgabe	Typ cue	Imagery cue
Der Patient setzt sich seitwärts auf die Bank (The patient sits sideways on a bench)	Kinästhetik (kinaesthetic)	Der Kopf des Patienten wird 45° in Richtung der nicht betroffenen Seite gedreht. (The patient's head is turned 45° towards the unaffected side)
	Kinästhetik (kinaesthetic)	Manuelle Unterstützung des Kopfes (Manual support of the head)

Schritt 2 (step 2)

Aufgabe	Typ cue	Imagery cue
Der Patient wird schnell in eine Seitlage-position gebracht (The patient is quickly brought into a side-lying position)	Visuell (visual)	Observation eines möglichen Nystagmus (Observation of a possible nystagmus)
	Kinästhetik (kinaesthetic)	Halten Sie den Kopf 45° weggedreht von der betroffenen Seite (Keep the head 45° turned away from the affected side)
	Kinästhetik (kinaesthetic)	Stellen Sie sich stabil (breitbeinig) hin und führen Sie den Patienten mit einer Bewegung ihres ganzen Körpers (Position yourself stably (with your legs apart) and guide the patient with a movement of your whole body)
	Kollaborativ (collaborative)	Sagen Sie dem Patienten, dass er ihre Arme mit einem Kreuzgriff ergreifen kann (bei Unsicherheit) (Tell the patient that he can grasp your arms (in case of uncertainty)

Schritt 3 (step 3)

Aufgabe (task)	Type cue	Imagery cue
Der Therapeut bewegt den Patienten mit einer schnellen Bewegung in einer 180° Drehung auf die andere Seite (The therapist moves the patient to the other side with a fast 180° rotation)	Visuell (visual)	Observation eines möglichen Nystagmus (Observation of a possible nystagmus)
	Visuell (visual)	Der Patient schaut in Richtung des Bodens am Ende der Bewegung (The patient looks towards the floor at the end of the movement)
	Kinästhetik (kinaesthetic)	Der Therapeut kontrolliert das Alignment des Kopfs und Rumpfs bei der Bewegung (The therapist controls the alignment of the head and trunk during the movement)
	Kinästhetik (kinaesthetic)	Stellen Sie sich stabil (breitbeinig) hin und führen Sie den Patienten mit einer Bewegung ihres ganzen Körpers (Position yourself stably (with your legs apart) and guide the patient with a movement of your whole body)
	Kollaborativ (collaborative)	Sagen Sie dem Patienten, dass er ihre Arme mit einem Kreuzgriff ergreifen kann (bei Unsicherheit) (Tell the patient that he can grasp your arms (in case of uncertainty)
	Kognitiv (cognitive)	Die Bewegung wird ohne Stop in der Mitte durchgeführt (The movement is carried out without a stop in the middle)

Schritt 4 (step 4)

Aufgabe	Typ cue	Imagery cue
Head shake (optional)	Visuell (visual)	Observation eines möglichen Nystagmus (Observation of a possible nystagmus)
	Kinästhetik (kinaesthetic)	Der Therapeut schüttelt den Kopf des Patienten 1 - 2 x mit einer kleinen Amplitude (The therapist shakes the patient's head 1 - 2 times with a small amplitude)
	Kognitiv (cognitive)	Wird nur durchgeführt, wenn der Patient keine Symptome bei Schritt 3 angibt (Is only performed if the patient does not specify any symptoms during step 3)

Schritt 5 (step 5)

Aufgabe (task)	Type cue	Imagery cue
Der Patient wird langsam in den Sitz geführt (The patient is slowly guided into a sitting position)	Visuell (visual)	Observation eines möglichen Nystagmus (Observation eines möglichen Nystagmus)
	Kinästhetik (kinaesthetic)	Stellen Sie sich stabil (breitbeinig) hin und führen Sie den Patienten mit einer Bewegung ihres ganzen Körpers (Position yourself stably (with your legs apart) and guide the patient with a movement of your whole body)
	Kollaborativ (collaborative)	Sagen Sie dem Patienten, dass er ihre Arme mit einem Kreuzgriff ergreifen kann (bei Unsicherheit) (Tell the patient that he can grasp your arms (in case of uncertainty)

Schritt 6 (step 6)

Aufgabe (task)	Type cue	Imagery cue
Der Therapeut gibt “Post-procedure” Instruktionen (The therapist provides post-procedure instructions)	Kognitiv (cognitive)	Der Patient sollte für die nächsten 20 Minuten eine aufrechte Position einnehmen (The patient should maintain an upright position for the next 20 minutes)
	Kognitiv (cognitive)	Instruieren Sie dem Patienten die LM Prozedur als Heimprogramm (Instruct the LM procedure as a home programme)

LEArN Trial

Vestibular rehabilitation

LEArN Trial

Gruppe (group) 2C

Dix-Hallpike Test

Vorbereitung (preparation)

Aufgabe (task)	Spezifische Aufgabe (specific task)
Allgemeine Information (general information)	Erklären Sie dem Patienten die Prozedur. (Explain the procedure to the patient)
	Stellen Sie einen Eimer bereit, falls dem Patienten "schlecht" wird (Provide a bucket in case the patient gets "sick").
	Erklären Sie dem Patienten, dass er bei den folgenden Schritten aktiv mitbewegen soll. (Explain to the patient that he should actively participate in the following steps)

Schritt (step) 1

Aufgabe (task)	Spezifische Aufgabe (specific task)
Der Patient setzt sich in Langsitz-position auf die Bank (The patient sits on the bench)	Stellen Sie sich neben den Patienten. (Stand next to the patient)
	Brillen sollten abgenommen werden. (Glasses should be removed)
	Der pSCC* des Ohres, dass am bodennächsten ist, wird am stärksten provoziert. Der aSCC* wird aber auch provoziert. (The pSCC* of the ear that is closest to the ground is provoked the most. The aSCC* is also provoked)

*pSCC: posterior semicircular canal
*aSCC: anterior semicircular canal

Schritt (step) 2

Aufgabe (task)	Spezifische Aufgabe (specific task)
Der Kopf des Patienten wird 45° rotiert (in Richtung der zu testenden Seite) (The patient's head is rotated 45° (in the direction of the side to be tested))	Der Kopf und Nacken des Patienten müssen stabil sein (The patient's head and neck must be stable)
	Achten Sie darauf die 45° Stellung des Kopfes bei den folgenden Schritten beizubehalten. (Be sure to maintain the 45° rotation of the head during the following steps)
	Sagen Sie dem Patienten, dass er sich mit einem Kreuzgriff bei ihnen festhalten kann (bei Unsicherheit) (Tell the patient that he can hold on to you (in case of uncertainty))

Schritt (step) 3

Aufgabe (task)	Spezifische Aufgabe (specific task)
Der Patient wird in die Rücklage gebracht. Das zu testende Ohr liegt unten. (The patient is placed in supine position. The ear to be tested is below)	Führen Sie den Patienten in die Rücklage. Der Patient bewegt sich “en bloc” nach unten. (Move the patient into a supine position. The patient moves "en bloc" downwards)
	Der Kopf und Nacken des Patienten müssen stabil sein (The patient's head and neck must be stable)
	Das Kinn sollte nach oben zeigen und der Kopf sollte über der Bank hängen (20° Extension) (The chin should point upwards and the head should hang over the bench (20° extension))
	Kontrollieren Sie die Augen des Patienten im Bezug auf Nystagmus (Dauer und Richtung) (Check the patient's eyes for nystagmus (duration and direction))
	Bei einer Läsion des pSCC “upbeat” Nystagmus, aSCC “downbeat” nystagmus” (In case of a lesion of the pSCC "upbeat" nystagmus, aSCC "downbeat" nystagmus)
	Fragen Sie den Patienten nach Vertigo. (Ask the patient about Vertigo)
	Sagen Sie dem Patienten, dass er sich mit einem Kreuzgriff bei ihnen festhalten kann (bei Unsicherheit) (Tell the patient that he can hold on to you (in case of uncertainty))

*pSCC: posterior semicircular canal
*aSCC: anterior semicircular canal

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Schritt (step) 4

Aufgabe (task)	Spezifische Aufgabe (specific task)
Der Patient wird langsam wieder in den Langsitz gebracht. (The patient is slowly brought back into a sitting position)	Starten Sie diesen Schritt, wenn die Symptome und der Nystagmus nachgelassen haben.
	Kontrollieren Sie die Augen des Patienten im Bezug auf Nystagmus (Dauer und Richtung) (Check the patient's eyes for nystagmus (duration and direction))
	Der Kopf und Nacken des Patienten müssen stabil sein (The patient's head and neck must be stable)
	Führen Sie den Patienten langsam zurück in den Langsitz. (Slowly return the patient to a sitting position)
	Fragen Sie den Patienten nach Vertigo. (Ask the patient about vertigo)
	Sagen Sie dem Patienten, dass er sich mit einem Kreuzgriff bei ihnen festhalten kann (bei Unsicherheit) (Tell the patient that he can hold on to you (in case of uncertainty))

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Schritt (step) 5

Aufgabe (task)	Spezifische Aufgabe (specific task)
Der Test wird auf der anderen Seite durchgeführt (The test is performed on the other side)	Stellen Sie sich neben den Patienten. (Stand next to the patient)
	Brillen sollten abgenommen werden. (Glasses should be removed)
	Der pSCC* des Ohres, dass am bodennächsten ist, wird am stärksten provoziert. Der aSCC* wird aber auch provoziert. (The pSCC* of the ear that is closest to the ground is provoked the most. The aSCC* is also provoked)

*pSCC: posterior semicircular canal
*aSCC: anterior semicircular canal

Canalith repositioning technique (CRT)

Vorbereitung (preparation)

Aufgabe (task)	Spezifische Aufgabe (specific task)
Allgemeine Information (general information)	Erklären Sie dem Patienten die Prozedur. (Explain the procedure to the patient).
	Stellen Sie einen Eimer bereit, falls dem Patienten “schlecht” wird. (Provide a bucket in case the patient gets “sick")
	Timing: Es ist nicht notwendig, dass sich der Patient schnell durch die Positionen bewegt. (Timing: It is not necessary for the patient to move quickly through the positions)
	Der Patient muss in einer Position bleiben bis die Symptome nachlassen. Falls keine Symptome anwesend sind orientieren Sie sich an der Dauer der Symptome in dem vorgegangenem Test (The patient must stay in one position until symptoms subside. If no symptoms are present, use duration of the symptoms in the previous test as orientation)
	Erklären Sie dem Patienten, dass er bei den folgenden Schritten aktiv mithelfen soll. (Explain to the patient that he should actively participate in the following steps)

Schritt (step) 1

Aufgabe (task)	**Spezifische Aufgabe (specific task)**
Der Patient setzt sich in Langsitz-position auf die Bank und der Kopf wird 45° zur betroffenen Seite gedreht. (The patient sits on the bench and the head is turned 45° to the affected side)	Stellen Sie sich neben den Patienten. (Stand next to the patient)
	Unterstützen Sie den Kopf des Patienten (Support the patient's head)

Schritt (step) 2

Aufgabe (task)	**Spezifische Aufgabe (specific task)**
Der Patient wird in die Dix-Hallpike Position auf der betroffenen Seite gebracht (d.h. links betroffen; der Kopf ist 45° nach links gedreht) (The patient is placed into the Dix-Hallpike position on the affected side (i.e. affected on the left; the head is turned 45° to the left)	Der Kopf des Patienten sollte über der Bank hängen (in Extension) (The patient's head should hang over the bench (in extension)
	Kontrollieren Sie die Kopfposition des Patienten (45° Rotation und ~20 Extension) (Check the head position of the patient (45° rotation and ~20 extension)
	Führen Sie den Patienten in die Rücklage. Der Patient bewegt sich “en bloc” nach unten. (Move the patient into a supine position. The patient moves "en bloc" downwards)
	Der Patient bleibt in der Position bis die Symptome nachlassen (The patient remains in this position until symptoms subside)
	Sagen Sie dem Patienten, dass er sich mit einem Kreuzgriff bei ihnen festhalten kann (bei Unsicherheit) (Tell the patient that he can hold on to you (in case of uncertainty))

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Schritt (step) 3

Aufgabe (task)	**Spezifische Aufgabe (specific task)**
Der Kopf des Patienten wird 90° in Richtung der nicht betroffenen Seite gedreht (The patient's head is turned 90° towards the unaffected side)	Halten Sie den Kopf des Patienten in einer moderaten Extension (~20°) während der Drehung (Hold the patient's head in a moderate extension (~20°) during the rotation)
	Der Patient bleibt in der Position bis die Symptome nachlassen (The patient remains in this position until symptoms subside)

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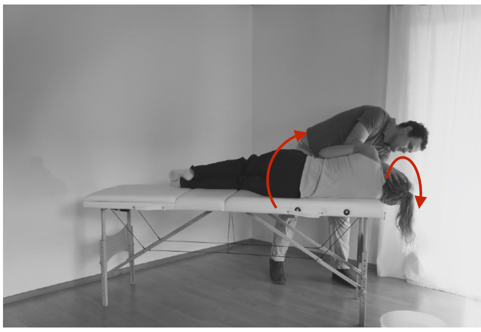
Schritt (step) 4

Aufgabe (task)	**Spezifische Aufgabe (specific task)**
Der Patient rollt auf seine Seite und der Kopf schaut in Richtung Boden (The patient rolls onto his side and his head points towards the floor)	Der Kopf wird 45° in Richtung des Bodens gedreht (die nicht betroffene Seite ist bodennah) (The head is turned 45° towards the ground (the unaffected side is near the ground))
	Der Patient bleibt in der Position bis die Symptome nachlassen (The patient remains in this position until symptoms subside)



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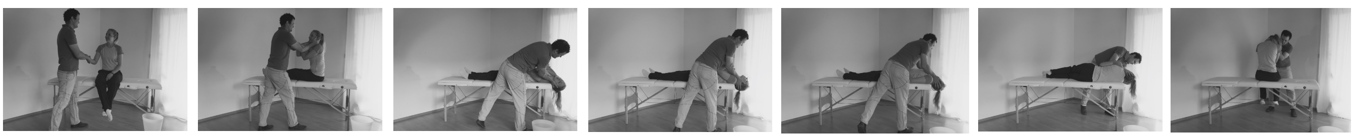
Schritt (step) 5

Aufgabe (task)	Spezifische Aufgabe (specific task)
Der Patient setzt sich langsam aufrecht hin (The patient slowly gets up)	Die Drehung des Kopfes (45° in Richtung der nicht betroffenen Seite) wird beibehalten (The rotation of the head (45°towards the unaffected side) is maintained)
	Der Kopf wird in einer leichten Flexion eingestellt (The head is positioned in a slight flexion)
	Führen Sie den Patienten langsam zurück in die Sitzposition (Slowly return the patient to the sitting position)
	Sagen Sie dem Patienten, dass er sich mit einem Kreuzgriff bei ihnen festhalten kann (bei Unsicherheit) (Tell the patient that he can hold on to you (in case of uncertainty))
	Bei einigen Patienten treten die Symptome im Sitz wieder auf. (The symptoms may reappear in this position)

Schritt (step) 6

Aufgabe (task)	Imagery cue
Der Therapeut gibt “Post-procedure” Instruktionen (The therapist provides post-procedure instructions)	Der Patient sollte eine aufrechte Position einnehmen für die nächsten 20 Minuten (The patient should maintain an upright position for the next 20 minutes)
	Instruieren Sie dem Patienten die CRT Prozedur als Heimprogramm (Instruct the CRT procedure as a home programme)



Liberatory manoeuvre (LM)

Vorbereitung (preparation)

Aufgabe (task)	Spezifische Aufgabe (specific task)
Allgemeine Information (general information)	Erklären Sie dem Patienten die Prozedur. (Explain the procedure to the patient).
	Die "LM" Prozedur kann anstelle des CRT durchgeführt werden, falls Patienten keine Extension der HWS durchführen können (The "LM" procedure can be performed instead of the "CRT" if patients are unable to extend the cervical spine.)
	Stellen Sie einen Eimer bereit, falls dem Patienten "schlecht" wird. (Provide a bucket in case the patient gets "sick")
	Bleiben Sie in einer Position bis die Symptome nachlassen. Falls keine Symptome anwesend sind orientieren Sie sich an der Dauer der Symptome in dem vorgegangenem Test (Stay in one position until symptoms subside. If no symptoms are present, use duration of the symptoms in the previous test as orientation)
	Erklären Sie dem Patienten, dass er bei den folgenden Schritten aktiv mithelfen soll. (Explain to the patient that he should actively participate in the following steps)

Schritt (step) 1

Aufgabe (task)	Spezifische Aufgabe (specific task)
Der Patient setzt sich seitwärts auf die Bank (The patient sits sideways on a bench)	Der Kopf des Patienten wird 45° in Richtung der nicht betroffenen Seite gedreht. (The patient's head is turned 45° towards the unaffected side)
	Unterstützen Sie den Kopf des Patienten (Support the patient's head)

Schritt (step) 2

Aufgabe (task)	Spezifische Aufgabe (specific task)
Der Patient wird schnell in eine Seitlageposition gebracht (The patient is quickly brought into a side-lying position)	Kontrollieren Sie die Augen des Patienten im Bezug auf Nystagmus (Dauer und Richtung) (Check the patient's eyes for nystagmus (duration and direction))
	Halten Sie den Kopf 45° weggedreht von der betroffenen Seite (Keep the head 45° turned away from the affected side)
	Führen Sie den Patienten in die Seitlage. Der Patient bewegt sich “en bloc” nach unten (Guide the patient into the side-lying position. The patient moves "en bloc" downwards)
	Sagen Sie dem Patienten, dass er sich mit einem Kreuzgriff bei ihnen festhalten kann (bei Unsicherheit) (Tell the patient that he can hold on to you (in case of uncertainty))

Schritt (step) 3

Aufgabe (task)	Spezifische Aufgabe (specific task)
Der Patienten wird schnell 180° auf die andere Seite gedreht (The patient is quickly turned 180° to the other side)	Kontrollieren Sie die Augen des Patienten im Bezug auf Nystagmus (Dauer und Richtung) (Check the patient's eyes for nystagmus (duration and direction))
	Der Patient schaut in Richtung des Bodens am Ende der Bewegung (The patient looks towards the floor at the end of the movement)
	Der Therapeut kontrolliert das Alignment des Kopfs und Rumpfs bei der Bewegung (The therapist controls the alignment of the head and trunk during the movement)
	Führen Sie den Patienten mit einer schnellen Bewegung. (Guide the patient with a quick movement)
	Sagen Sie dem Patienten, dass er sich mit einem Kreuzgriff bei ihnen festhalten kann (bei Unsicherheit) (Tell the patient that he can hold on to you (in case of uncertainty))
	Der Patient sollte 180° gedreht werden, ohne Stop in der Mitte (The patient should be moved 180°, without a stop in the mid-position)

Schritt (step) 4

Aufgabe (task)	Spezifische Aufgabe (specific task)
	Kontrollieren Sie die Augen des Patienten im Bezug auf Nystagmus (Dauer und Richtung) (Check the patient's eyes for nystagmus (duration and direction))
Head shake (optional)	Der Kopf des Patienten wird 1 - 2 x einige Zentimeter von der Bank abgehoben (The patient's head is lifted 1 - 2 x a few centimetres from the bench)
	Wird nur durchgeführt, wenn der Patient keine Symptome bei Schritt 3 angibt (Is only performed if the patient does not specify any symptoms during step 3)

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Schritt (step) 5

Aufgabe (task)	Spezifische Aufgabe (specific task)
	Kontrollieren Sie die Augen des Patienten im Bezug auf Nystagmus (Dauer und Richtung) (Check the patient's eyes for nystagmus (duration and direction))
Der Patient wird langsam in den Sitz geführt (The patient is slowly guided into a sitting position)	Führen Sie den Patienten langsam zurück in die Sitzposition (Slowly return the patient to the sitting position)
	Sagen Sie dem Patienten, dass er sich mit einem Kreuzgriff bei ihnen festhalten kann (bei Unsicherheit) (Tell the patient that he can hold on to you (in case of uncertainty))

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Schritt (step) 6

Aufgabe (task)	Imagery cue
Der Therapeut gibt “Post-procedure” Instruktionen (The therapist provides post-procedure instructions)	Der Patient sollte für die nächsten 20 Minuten eine aufrechte Position einnehmen (The patient should maintain an upright position for the next 20 minutes)
	Instruieren Sie dem Patienten die LM Prozedur als Heimprogramm (Instruct the LM procedure as a home programme)

LEArN Trial

Vestibular rehabilitation

LEArN Trial

Gruppe (group) 2D

Dix-Hallpike Test

Vorbereitung (preparation)

Aufgabe (task)	**Spezifische Aufgabe (specific task)**
Allgemeine Information (general information)	Erklären Sie dem Patienten die Prozedur. (Explain the procedure to the patient)
	Stellen Sie einen Eimer bereit, falls dem Patienten “schlecht” wird. (Provide a bucket in case the patient gets “sick”)
	Erklären Sie dem Patienten, dass er bei den folgenden Schritten aktiv mitbewegen soll. (Explain to the patient that he should actively participate in the following steps)

Schritt (step) 1

Aufgabe (task)	Spezifische Aufgabe (specific task)
Helfen Sie dem Patienten, (mit ihren Armen) in eine Langsitzposition zu kommen (Help the patient (with your arms) to get into a sitting position)	Stellen Sie sich mit aufrechtem Rumpf neben den Patienten (Stand with your trunk upright next to the patient)
	Brillen sollten abgenommen werden. (Glasses should be removed)
	Stellen Sie mit ihren Händen den Kopf des Patienten so ein, dass das zu testende Ohr am bodennächsten ist (dieser pSCC* wird hauptsächlich provoziert. Zu einem geringerem Anteil wird auch der aSCC* provoziert). (Postion the patient's head with your hands so that the ear to be tested is closest to the ground (this pSCC* is mainly provoked. The aSCC* is also provoked))

*pSCC: posterior semicircular canal
*aSCC: anterior semicircular canal

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Schritt (step) 2

Aufgabe (task)	Spezifische Aufgabe (specific task)
Drehen Sie den Kopf des Patienten mit ihren Händen 45° in Richtung der zu testenden Seite (Turn the patient's head with your hands 45° towards the side to be tested)	Platzieren Sie ihre Hände seitlich am Kopf des Patienten (um die Ohren) und unterstützen Sie den Kopf (Place your hands on the side of the patient's head (around the ears) and support the head)
	Achten Sie darauf, mit ihren Hände die 45° Stellung des Kopfes bei den folgenden Schritten zu kontrollieren (Be sure to check the 45° position of the head with your hands during the following steps)
	Lassen Sie den Patienten ihre Arme im Bereich der Ellenbogen mit einem Kreuzgriff ergreifen (bei Unsicherheit) (Let the patient grasp your arms in the area of your elbows (in case of uncertainty))

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Schritt (step) 3

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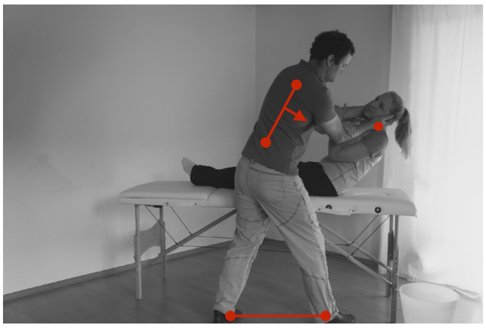
Aufgabe (task)	Spezifische Aufgabe (specific task)
Bringen Sie den Patienten durch eine Gewichts-verlagerung in die Rücklage (das zu testende Ohr liegt unten) (Perform a weight shift and position the patient in a supine position (the ear to be tested is below))	Führen Sie den Patienten mit einer Vorwärtsbewegung ihres Rumpfes in die Rücklage. Richten Sie ihre Beine so aus, dass sie stabil stehen (Guide the patient into the supine position with a forward movement of your trunk. Align your legs so that they are stable)
	Platzieren Sie ihre Hände seitlich am Kopf des Patienten und unterstützen Sie den Kopf (Place your hands on the side of the patient's head and support the head)
	Benutzen Sie ihre Hände, um den Kopf des Patienten in eine Extension zu bringen (~20°) (Use your hands to bring the patient's head into an extension
	Observieren der Augen des Patienten im Bezug auf Nystagmus (Dauer und Richtung) (Observe the patient's eyes in relation to nystagmus (duration and direction))
	Bei einer Läsion des pSCC* "upbeat" Nystagmus, aSCC* "downbeat" nystagmus" (In case of a lesion of the pSCC "upbeat" nystagmus, aSCC "downbeat" nystagmus)
	Fragen Sie den Patienten nach Vertigo. (Ask the patient about Vertigo)
	Lassen Sie den Patienten ihre Arme im Bereich der Ellenbogen mit einem Kreuzgriff ergreifen (bei Unsicherheit) (Let the patient grasp your arms in the area of your elbows (in case of uncertainty))



*pSCC: posterior semicircular canal
*aSCC: anterior semicircular canal

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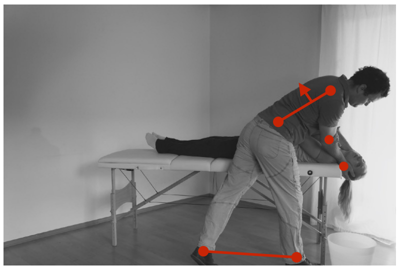
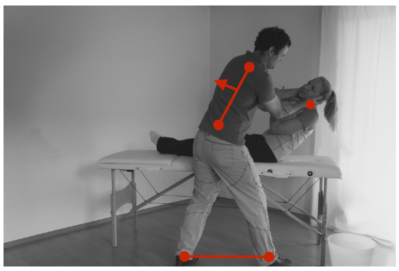
Schritt (step) 4

Aufgabe (task)	Spezifische Aufgabe (specific task)
Bringen Sie den Patienten durch eine Gewichts-verlagerung wieder in den Langsitz (Perform a weight shift and bring the patient back into the sitting position)	Starten Sie diesen Schritt, wenn die Symptome und der Nystagmus nachgelassen haben (Start this step when symptoms and nystagmus have subsided)
	Observieren der Augen des Patienten im Bezug auf Nystagmus (Dauer und Richtung) (Observe the patient's eyes in relation to nystagmus (duration and direction))
	Platzieren Sie ihre Hände seitlich am Kopf des Patienten und unterstützen Sie den Kopf (Place your hands on the side of the patient's head and support the head)
	Richten Sie ihre Beine so aus, dass sie stabil stehen. Richten Sie ihren Körper auf und verlagern Sie ihr Gewicht auf das hintere Bein. Führen Sie den Patienten mit einer Bewegung ihres ganzen Körpers (Align your legs so that they are stable. Align your body and shift your weight to the back leg. Guide the patient with a movement of your whole body)
	Fragen Sie den Patienten nach Vertigo (Ask the patient about Vertigo)
	Lassen Sie den Patienten ihre Arme im Bereich der Ellenbogen mit einem Kreuzgriff ergreifen (bei Unsicherheit) (Let the patient grasp your arms in the area of your elbows (in case of uncertainty))





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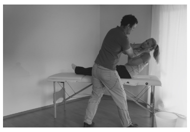
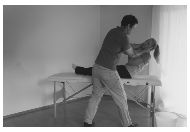
Schritt (step) 5

Aufgabe (task)	Spezifische Aufgabe (specific task)
Der Test wird auf der anderen Seite durchgeführt (The test is performed on the other side)	Stellen Sie sich mit aufrechtem Rumpf neben den Patienten (Stand with your trunk upright next to the patient)
	Brillen sollten abgenommen werden. (Glasses should be removed)
	Stellen Sie mit ihren Händen den Kopf des Patienten so ein, dass das zu testende Ohr am bodennächsten ist (dieser pSCC* wird hauptsächlich provoziert. Zu einem geringerem Anteil wird auch der aSCC* provoziert). (Postion the patient's head with your hands so that the ear to be tested is closest to the ground (this pSCC* is mainly provoked. The aSCC* is also provoked))








*pSCC: posterior semicircular canal
*aSCC: anterior semicircular canal

Canalith repositioning technique (CRT)

Vorbereitung (preparation)

Aufgabe (task)	Spezifische Aufgabe (specific task)
Allgemeine Information (general information)	Erklären Sie dem Patienten die Prozedur. (Explain the procedure to the patient)
	Stellen Sie einen Eimer bereit, falls dem Patienten “schlecht” wird. (Provide a bucket in case the patient gets “sick”)
	Timing: Es ist nicht notwendig, dass Sie sich schnell durch die Positionen bewegen (Timing: It is not necessary that you move quickly through the positions)
	Bleiben Sie in einer Position bis die Symptome nachlassen. Falls keine Symptome anwesend sind orientieren Sie sich an der Dauer der Symptome in dem vorgegangenem Test (Stay in one position until symptoms subside. If no symptoms are present, use duration of the symptoms in the previous test as orientation)
	Erklären Sie dem Patienten, dass er bei den folgenden Schritten aktiv mithelfen soll. (Explain to the patient that he should actively participate in the following steps)

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Schritt (step) 1

Aufgabe (task)	Spezifische Aufgabe (specific task)
Helfen Sie dem Patienten (mit ihren Armen) in eine Langsitzposition zu kommen (Help the patient (with your arms) to get into a sitting position)	Stellen Sie sich mit aufrechtem Rumpf neben den Patienten (Stand with your trunk upright next to the patient)
	Platzieren Sie ihre Hände seitlich am Kopf des Patienten und unterstützen Sie den Kopf. Führen Sie eine Drehbewegung mit ihren Handgelenken aus, um den Kopf des Patienten 45° zur betroffenen Seite zu drehen. (Place your hands on the side of the patient's head and support the head. Turn your wrists to rotate the patient's head 45° to the affected side)

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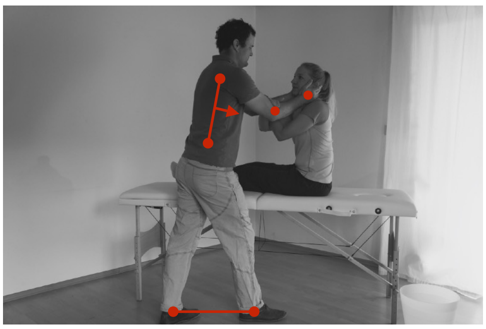
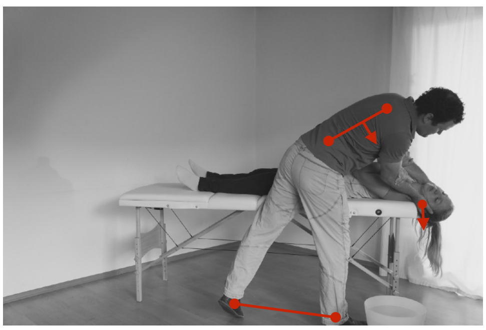
Schritt (step) 2

Aufgabe (task)	Spezifische Aufgabe (specific task)
Bringen Sie den Patienten mit einer Gewichtsverlagerung in die Dix-Hallpike Position auf der betroffenen Seite (d.h. links betroffen; der Kopf ist 45° nach links gedreht) (Perform a weight shift and position the patient into the Dix-Hallpike position on the affected side)	Benutzen Sie ihre Hände, um den Kopf des Patienten in eine Extension zu bringen (~20°) (Use your hands to bring the patient's head into an extension (~20°))
	Verhindern Sie mit ihren Armstellung, dass der Patient seine Kopfstellung verändert (45° Rotation) (Prevent the patient from changing his or her head position (45° rotation) with your arms)
	Führen Sie den Patienten mit einer Vorwärtsbewegung ihres Rumpfes und einer Gewichtsverlagerung in die Rücklage. Richten Sie ihre Beine so aus, dass sie stabil stehen (Guide the patient into the supine position, with a forward movement of your trunk and a weight shift. Align your legs so that they are stable))
	Bleiben Sie in dieser Körperposition bis die Symptome nachlassen (Stay in this position until symptoms subside)
	Lassen Sie den Patienten ihre Arme im Bereich der Ellenbogen mit einem Kreuzgriff ergreifen (bei Unsicherheit) (Let the patient grasp your arms in the area of your elbows (in case of uncertainty))





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Schritt (step) 3

Aufgabe (task)	**Spezifische Aufgabe (specific task)**
Bewegen Sie ihre Arme zusammen mit dem Kopf des Patienten um 90° in Richtung der nicht betroffenen Seite (Move your arms together with the patient's head 90° towards the unaffected side)	Halten Sie ihre Arme gestreckt während der Drehung, um die Extension des Nackens (~20°) beizubehalten. (Keep your arms extended during the rotation to maintain the neck extension (~20°))
	Bleiben Sie in dieser Körperstellung bis die Symptome des Patienten nachlassen (Stay in this position until the patient's symptoms subside)

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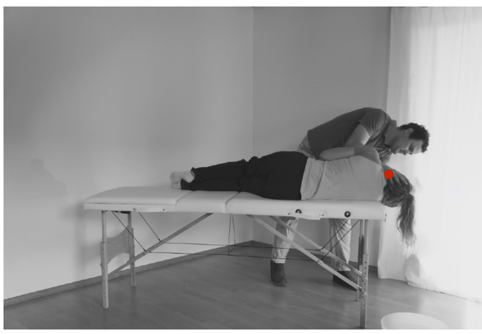
Schritt (step) 4



Aufgabe (task)	**Spezifische Aufgabe (specific task)**
Führen Sie den Patienten in die Seitlage. Ihre Hände drehen den Kopf vorsichtig in Richtung Boden (Guide the patient in a side-lying position. Your hands turn the head carefully towards the floor)	Benutzen Sie Ihre Hände, um den Kopf des Patienten vorsichtig 45° in Richtung des Bodens zu drehen (die nicht betroffene Seite ist bodennah). (Use your hands to carefully rotate the patient's head 45° towards the floor (the unaffected side is near the floor))
	Bleiben Sie in dieser Körperstellung bis die Symptome nachlassen (Stay in this position until the symptoms subside)

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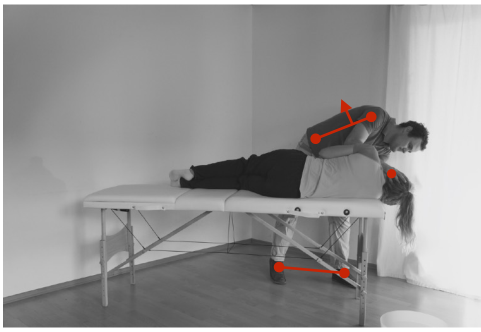
Schritt (step) 5

Aufgabe (task)	Spezifische Aufgabe (specific task)
Bringen Sie den Patienten durch eine Gewichts-verlagerung wieder in eine Sitzposition (Perform a weight shift and bring the patient back into a sitting position)	Achten Sie darauf, dass Sie mit ihren Armen den Kopf des Patienten 45° in Richtung der nicht betroffenen Seite gedreht halten (Make sure that your arms keep the patient's head turned 45° towards the unaffected side)
	Beugen Sie den Kopf des Patienten, indem sie mit ihren Händen am Nacken des Patienten einen leichten Druck geben (Bend the patient's head by applying light pressure to the patient's neck with your hands)
	Richten Sie ihre Beine so aus, dass sie stabil stehen. Richten Sie ihren Körper auf und verlagern Sie ihr Gewicht auf das hintere Bein. Führen Sie den Patienten mit einer Bewegung ihres ganzen Körpers (Align your legs so that they are stable. Align your body and shift your weight to the back leg. Guide the patient with a movement of your whole body)
	Lassen Sie den Patienten ihre Arme im Bereich der Ellenbogen mit einem Kreuzgriff ergreifen (bei Unsicherheit) (Let the patient grasp your arms in the area of your elbows (in case of uncertainty))
	Bei einigen Patienten treten die Symptome im Sitz wieder auf (The symptoms may reappear in this position)



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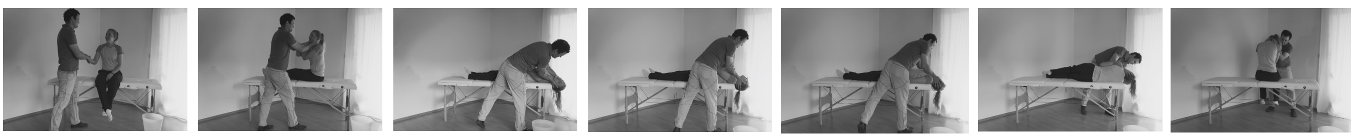
Schritt (step) 6

Aufgabe (task)	Imagery cue
Der Therapeut gibt "Post-procedure" Instruktionen (The therapist provides post-procedure instructions)	Der Patient sollte eine aufrechte Position einnehmen für die nächsten 20 Minuten (The patient should maintain an upright position for the next 20 minutes)
	Instruieren Sie dem Patienten die CRT Prozedur als Heimprogramm (Instruct the CRT procedure as a home programme)



LEArN Trial

Liberatory manoeuvre (LM)

Vorbereitung (preparation)

Aufgabe (task)	Spezifische Aufgabe (specific task)
Allgemeine Information (general information)	Erklären Sie dem Patienten die Prozedur. (Explain the procedure to the patient)
	Die “LM” Prozedur kann anstelle des CRT durchgeführt werden, falls Patienten keine Extension der HWS durchführen können (The "LM" procedure can be performed instead of the "CRT" if patients are unable to extend the cervical spine)
	Stellen Sie einen Eimer bereit, falls dem Patienten “schlecht” wird. (Provide a bucket in case the patient gets “sick”)
	Bleiben Sie in einer Position bis die Symptome nachlassen. Falls keine Symptome anwesend sind orientieren Sie sich an der Dauer der Symptome in dem vorgegangenem Test (Stay in one position until symptoms subside. If no symptoms are present, use duration of the symptoms in the previous test as orientation)
	Erklären Sie dem Patienten, dass er bei den folgenden Schritten aktiv mithelfen soll. (Explain to the patient that he should actively participate in the following steps)

Schritt 1

Aufgabe (task)	Spezifische Aufgabe (specific task)
Der Patient setzt sich seitwärts auf die Bank (The patient sits sideways on a bench)	Führen Sie eine Drehbewegung mit ihren Armen aus, um den Kopf des Patienten 45° zur nicht betroffenen Seite zu drehen. (Turn your arms to rotate the patient's head 45° to the unaffected side)
	Platzieren Sie ihre Hände seitlich am Kopf des Patienten und unterstützen Sie den Kopf (Place your hands on the side of the patient's head and support the head).

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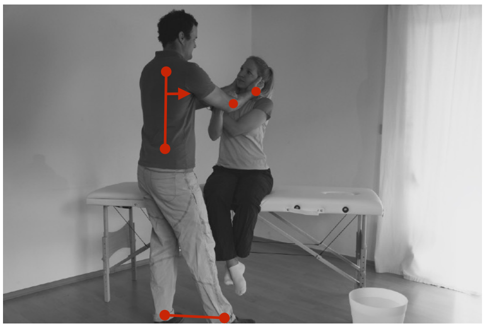
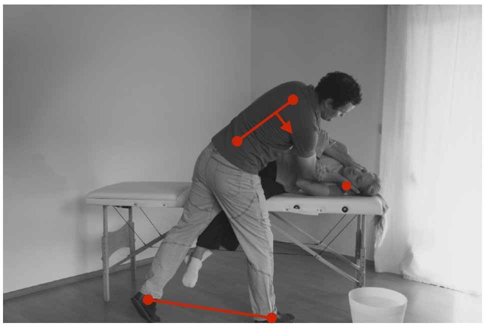
Schritt (step) 2

Aufgabe (task)	**Spezifische Aufgabe (specific task)**
Bringen Sie den Patienten durch eine Gewichts-verlagerung in eine Seiltageposition (Perform a weight shift and bring the patient into a side-lying position)	Observieren der Augen des Patienten im Bezug auf Nystagmus (Dauer und Richtung) (Observe the patient's eyes in relation to nystagmus (duration and direction))
	Kontrollieren Sie ihre Handstellung, so dass der Kopf des Patienten 45° weggedreht von der betroffenen Seite bleibt (Check your hand position so that the patient's head remains turned 45° away from the affected side)
	Führen Sie den Patienten mit einer Vorwärtsbewegung ihres Rumpfes und einer Gewichtsverlagerung in die Seitlage. Richten Sie ihre Beine so aus, dass sie stabil stehen (Guide the patient into a side-lying position with a forward movement of your trunk and a weight shift. Align your legs so that you are stable)
	Lassen Sie den Patienten ihre Arme im Bereich der Ellenbogen mit einem Kreuzgriff ergreifen (bei Unsicherheit) (Let the patient grasp your arms in the area of your elbows (in case of uncertainty))





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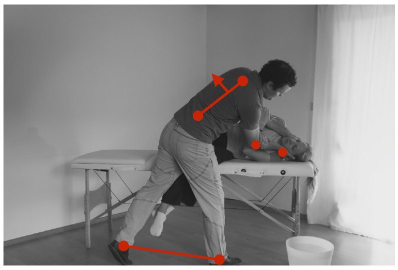
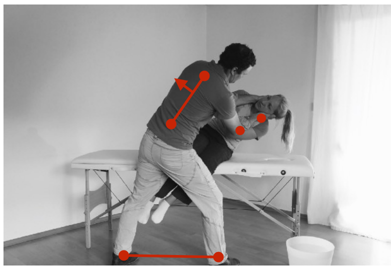
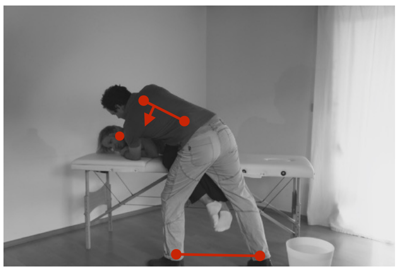
Schritt (step) 3

Aufgabe (task)	**Spezifische Aufgabe (specific task)**
Drehen Sie den Patienten durch eine schnelle Gewichts-verlagerung 180° auf die andere Seite (Perform a weight shift and turn the patient 180° to the other side)	Observieren der Augen des Patienten im Bezug auf Nystagmus (Dauer und Richtung) (Observe the patient's eyes in relation to nystagmus (duration and direction))
	Ihre Handstellung muss während der Bewegung konstant bleiben. So dass der Kopf des Patienten am Ende in Richtung Boden schaut (Your hand position must remain constant during the movement. So that the patient's head faces towards the floor at the end position)
	Spannen Sie ihre Armmuskeln vor der Bewegung an, um ein angemessenes Alignment des Patienten zu gewährleisten (Tighten your arm muscles before the movement to ensure proper alignment of the patient)
	Richten Sie ihre Beine so aus, dass sie stabil stehen. Richten Sie ihren Körper auf und verlagern Sie ihr Gewicht auf das andere Bein. Führen Sie den Patienten mit einer schnellen Bewegung ihres ganzen Körpers (Align your legs so that you are stable. Align your body and shift your weight to the other leg. Guide the patient with a quick movement of your whole body)
	Lassen Sie den Patienten ihre Arme im Bereich der Ellenbogen mit einem Kreuzgriff ergreifen (bei Unsicherheit) (Let the patient grasp your arms in the area of your elbows (in case of uncertainty))
	Stoppen Sie ihre Körperbewegung nicht in der Mitte (Don't stop your body movement in the middle)







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Schritt (step) 4

Aufgabe (task)	Spezifische Aufgabe (specific task)
Head shake (optional)	Observieren der Augen des Patienten im Bezug auf Nystagmus (Dauer und Richtung) (Observe the patient's eyes in relation to nystagmus (duration and direction))
	Führen Sie mit ihren Handgelenken 1-2 schnelle Bewegungen mit einer kleinen Amplitude durch (Use your wrists to make 1-2 fast movements with a small amplitude)
	Wird nur durchgeführt, wenn der Patient keine Symptome bei Schritt 3 angibt (Is only performed if the patient does not specify any symptoms in step 3)

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Schritt (step) 5

Aufgabe (task)	Spezifische Aufgabe (specific task)
Bringen Sie den Patienten durch eine Gewichts-verlagerung langsam in den Sitz (Perform a weight shift and guide the patient slowly into a sitting position)	Observieren der Augen des Patienten im Bezug auf Nystagmus (Dauer und Richtung) (Observe the patient's eyes in relation to nystagmus (duration and direction))
	Richten Sie ihre Beine so aus, dass sie stabil stehen. Richten Sie ihren Körper auf und verlagern Sie ihr Gewicht auf das hintere Bein. Führen Sie den Patienten mit einer Bewegung ihres ganzen Körpers (Align your legs so that you are stable. Align your body and shift your weight to the back leg. Guide the patient with a movement of your whole body)
	Lassen Sie den Patienten ihre Arme im Bereich der Ellenbogen mit einem Kreuzgriff ergreifen (bei Unsicherheit) (Let the patient grasp your arms in the area of your elbows (in case of uncertainty))

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Schritt (step) 6

Aufgabe (task)	Imagery cue
Der Therapeut gibt "Post-procedure" Instruktionen (The therapist provides post-procedure instructions)	Der Patient sollte für die nächsten 20 Minuten eine aufrechte Position einnehmen (The patient should maintain an upright position for the next 20 minutes)
	Instruieren Sie dem Patienten die LM Prozedur als Heimprogramm (Instruct the LM procedure as a home programme)